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THE COLD CURING OF CHEESE.

Report upon Experiments Conducted Under the Auspices of the U. S. Department of Agriculture, Bureau of Animal Industry, Dairy Division, in Cooperation with the Wisconsin Agricultural Experiment Station and the New York Agricultural Experiment Station.

BY

S. M. BABCOCK AND H. L. RUSSELL, ASSISTED BY U. S. BAER,
Madison, Wis.,
AND
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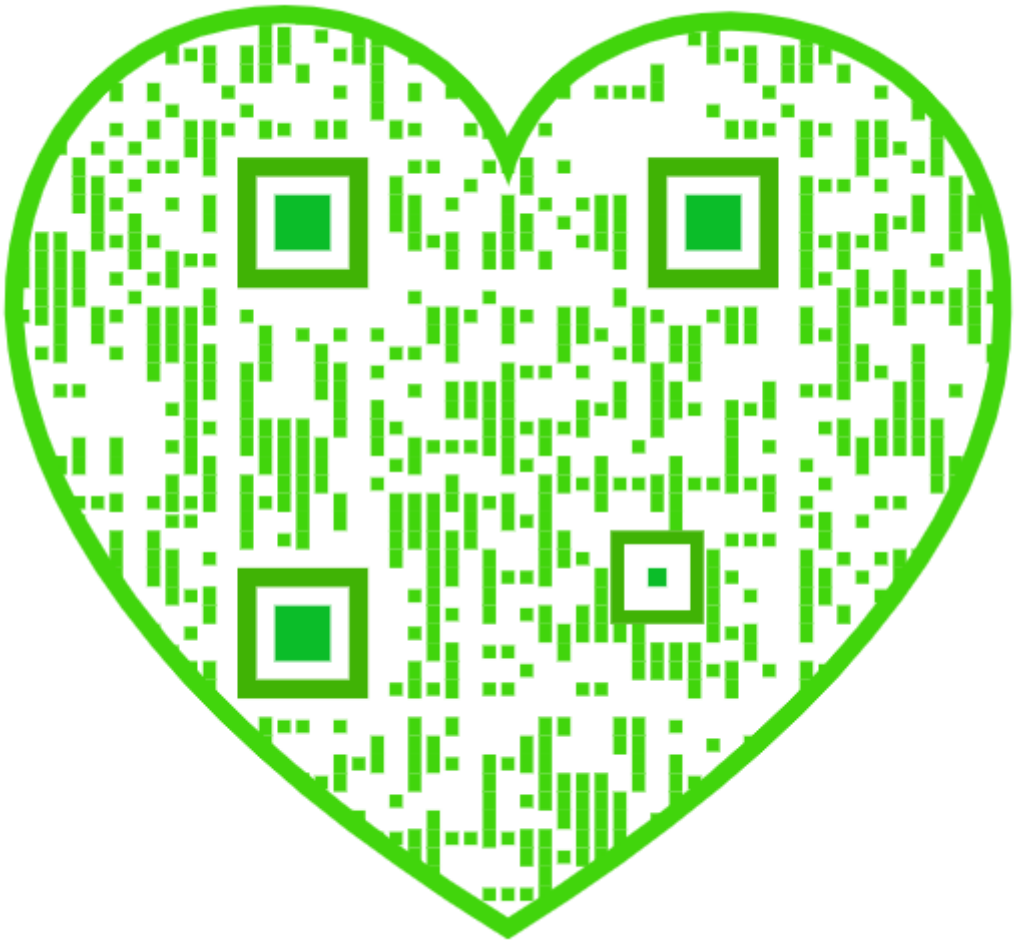

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[Continued on 3d page of cover.]

[a] Transferred, August 16, 1902, to U. S. Public Health and Marine-Hospital Service, as Chief of Division of Zoology, but remains also in temporary charge of Zoological Division, Bureau of Animal Industry.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ANIMAL INDUSTRY—Bulletin No. 49.

D. E SALMON, D. V. M., Chief of Bureau.

THE COLD CURING OF CHEESE.

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BY

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY,
Washington, D. C., August 1, 1903.

SIR: I have the honor to transmit herewith a manuscript on the cold-curing of cheese, being a report of a cooperative experiment of the Dairy Division and the experiment stations of Wisconsin and New York. The work has been very complete and the results satisfactory in a high degree, and I therefore recommend that this manuscript be published as a bulletin of this Bureau.

Respectfully,

D. E. SALMON,
Chief of Bureau.

HON. JAMES WILSON,
Secretary.

LETTER OF SUBMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY,
Washington, D. C., June, 1903.

SIR: I have the honor to submit herewith, in manuscript, reports made by officers of the agricultural experiment stations of Wisconsin and New York upon experiments in the cold-curing of cheese recently conducted in cooperation with the Department of Agriculture, and recommend publication of the same as a bulletin of this Bureau.

The work has been under the general supervision of the Dairy Division, and I desire to acknowledge the cordial cooperation of the two experiment stations named and their respective representatives, the material assistance of the cold-storage companies at Waterloo, Wis., and New York City, and the important and efficient services of the cheese experts who acted as scorers or judges, as described in the reports.

Very respectfully, yours,

HENRY E. ALVORD,
Chief of Dairy Division.

DR. D. E. SALMON,
Chief of Bureau of Animal Industry.

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THE COLD CURING OF CHEESE.

INTRODUCTION.

By Henry E. Alvord, C. E.,
Chief of Dairy Division, Bureau of Animal Industry.

The prevalent opinion among cheese dealers has always been that low temperatures, varying from 35° or 40° to 50° F., or thereabouts, resulted in the production of an inferior quality of cheese, in comparison with that from 60° to 70° F. No carefully controlled experiments bearing on this problem have been recorded earlier than those undertaken by Babcock and Russell at the Wisconsin Agricultural Experiment Station, and described in the Fourteenth (1897) Annual Report of that station. The results of those tests showed that cheese placed at refrigerator temperatures (45° to 50° F.),[a] directly from the press, was of superior quality as to flavor and also as to texture, and that such cheese was wholly free from any bitter or other undesirable taints.

In connection with their studies on the influence which galactase and rennet extract exert on the progress of cheese ripening, the same investigators later employed still lower temperatures (25° to 30° F.). Cheeses were kept at these excessively low curing temperatures for a period of eighteen months. The quality of these cheeses, cured as they were below the freezing point throughout their whole history, was exceptionally fine, and emphasized still more than the previous experiments did the fact that the ripening of cheese can go on at much lower temperatures than has heretofore been considered possible.

These results led to an extended series of experiments, in which cheese made on a commercial scale was cured at a range of temperature from below freezing (15° F.) to 60°—a point which common practice has now accepted as the best obtainable temperature that can be secured without the use of artificial refrigeration.

In these experiments (consisting of five series made at intervals throughout a period of two years) 138 cheeses were used, for which 30,000 pounds of milk were required. These experiments were upon a scale which represented commercial conditions, and therefore obvi-

[a] The first public presentation of these experiments was made at the meeting of the Wisconsin Cheesemakers' Association, in February, 1901.

ated the objection which is often urged in commercial practice against the application of results derived simply from laboratory experiments.

The results of these tests may be found detailed in Bulletin No. 94, and the Eighteenth (1901) and the Nineteenth (1902) Annual Reports of the Wisconsin Agricultural Experiment Station.

The Ontario Agricultural College began experiments on the cold curing of cheese in April, 1901. As a result of these tests, the conclusion was drawn that the cheese cured at low temperatures (37.8° F.) was much superior to that cured in ordinary curing rooms (average temperature during season 63.8° F.). Mr. R. M. Ballantyne, a prominent cheese expert, said of this cheese that "they [the merchants] universally expressed surprise at the condition of the cheese that was put into cold storage at the earliest period (that is, directly from the press), as they expected to find the cheese still curdy and probably with a bitter flavor." If this experiment is borne out by other experts, it would appear as if the best way to handle hot-weather cheese would be to ship it to the cold storage directly after making, and this would certainly mean a great revolution to the trade.[a]

More extensive experiments are in progress in Canada, but the results have not yet been published, although general statements have been made confirming previous conclusions.

A considerable number of experiments have also been made at other stations (Dominion government tests and New York State and Iowa experiment stations), where somewhat lower temperatures were used than those which are normally employed for ripening. The results obtained all show an improvement in quality that becomes more marked as the temperature is reduced.

In order that a much larger experiment might be instituted, covering the different types of cheese as represented by Eastern as well as Western manufacture, Drs. Babcock and Russell, of the Wisconsin Station, presented this matter for consideration to the Dairy Division of the Bureau of Animal Industry. As a result of this proposal the officers of the New York Agricultural Experiment Station were also consulted and plans perfected for the cooperative experiments conducted simultaneously in Wisconsin and New York, which are described in full in this bulletin. It should be noted that it was so late in the season of 1902 when the arrangements for this work were completed that it was impossible to obtain favorable conditions in all respects.

It was deemed desirable that the cheese to be tested should represent the product of as wide a range of territory as possible, and therefore it was decided to establish two curing stations—one in the East and the other in the West. Drs. S. M. Babcock and H. L. Russell were put in charge of the Western experiments and Dr. L. L. Van Slyke and Mr. G. A. Smith of those in the East.

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[a] Bulletin No. 121, Ontario Agricultural College, June, 1902.

OBJECTS OF THE EXPERIMENTS.

In addition to the influence which a range in temperature exerts on the quality of cheese, as determined by flavor and texture scores, instructions were also issued to secure data regarding the loss in weight which the different lots of cheese suffered at the different temperatures. The commercial quality of the product was to be determined by a jury of experts who were thoroughly in touch with the demands of the market. Although the effect of coating cheese with paraffin soon after being taken from the hoop was not at first proposed as a part of this work, it was finally included, both East and West.

The reasons for selecting 40°, 50°, and 60° F. as the temperatures to be used in these experiments are fully given on a later page. It may be assumed that the advantages of a cool and even temperature in curing Cheddar cheese have been already established in preference to a warm temperature or to very variable conditions which frequently include periods above 70° and sometimes much higher. As already stated, 60° or thereabouts is regarded as the lowest temperature practicable without artificial refrigeration; this may therefore be taken as fairly representative of what may be called a "cool" temperature for curing cheese. And rooms held at 40° and 50° were selected as representative of a "cold" temperature for curing, or comparatively so. It is thus hoped to emphasize by these experiments the distinction between cool curing and cold curing.

The cheese for these experiments was purchased by the United States Department of Agriculture, which also paid all expenses of transportation and storage and for the experts who made the periodical examinations. The two experiment stations selected the cheese, arranged all details of storage and examination, supervised the work throughout, performed the chemical and other incidental scientific work, kept the records, and reported results.

In order that a uniform system of scoring might be followed in the experiments, the appended score card was used for both:

EXPERIMENTS IN CURING CHEESE AT LOW TEMPERATURES, UNITED STATES DEPARTMENT OF AGRICULTURE, BUREAU OF ANIMAL INDUSTRY, DAIRY DIVISION.

Cheese judging—Numerical and descriptive score card.

Score for cheese (or sample) marked.....

NUMERICAL SCORE.

PERFECTION:	Flavor 45 points.	Texture 30 points.	Color 15 points.
SCORE:	do.	do.	do. .....

Date: ....., 190 . Initials of the judge: .....

DESCRIPTIVE SCORE. (Check the faults below.)

Flavor.		Texture and body.		Color.	
Perfect	Clean.....	Perfect	Silky	Perfect.....	
High	Flat or low	Smooth.....	Waxy.....	Straight.....	
Too high acid		Pasty.....	Salvy	Translucent.....	
Needs more acid		Stiff	Weak	White specks	
Sour.....	Sweet	Curdy	Mealy	Streaked.....	Wavy.....
Tainted	Weedy.....	Tallowy	Gritty	Mottled.....	Acid cut .....
Barny	Cowy.....	Close	Loose.....	Too high	Too light.....
Old milk	.....	Holes, mechanical		Uncolored	
Poor sewerage, dirty cans		Holes, gas	Holes, Swiss. ..		
		Watery	Too dry.....		

Each of the following reports, prepared by the two experiment stations participating in this work, treats the same general subject and similar lines of experiment and observation from its own point of view. The reports therefore differ in many respects, and yet they may be easily compared upon all essential points. Both support the following general conclusions:

ADVANTAGES OF CURING CHEESE AT LOW TEMPERATURES BRIEFLY SUMMARIZED.

(1) The loss of moisture is less at low temperatures, and therefore there is more cheese to sell.

(2) The commercial quality of cheese cured at low temperatures is better, and this results in giving the cheese a higher market value.

(3) Cheese can be held a long time at low temperatures without impairment of quality.

(4) By utilizing the combination of paraffining cheese and curing it at low temperatures the greatest economy can be effected.

THE WESTERN EXPERIMENTS, 1902–03.

Conducted by S. M. Babcock and H. L. Russell, assisted by U. S. Baer,
Of the Wisconsin Agricultural Experiment Station.

For the purposes of this experiment Chicago would naturally have been chosen as a curing station, but it was found difficult to make arrangements for the range of temperature desired. Suitable arrangements, however, were made at the cold-storage warehouse of the Roach & Seber Co., Waterloo, Wis., where rooms were fitted up and the desired temperatures secured.

SELECTION OF THE CHEESE.

As Wisconsin is the leading cheese-producing State of the West, the bulk of the product selected for experiment was of the type of cheese manufactured in this State. In order, however, to cover more thoroughly the cheese-producing territory of the West, samples were also secured from a number of the neighboring States. In this way all types of American cheese were obtained, ranging from the firm, typical Cheddar cheese, suitable for export, to the soft, open-bodied, moist cheese, intended for early consumption. For convenience we may group these various lots of cheese under three different types, as follows:

I. Close-bodied, firm, long-keeping type, suitable for export trade (typical Cheddar).

II. Sweet-curd type.

III. Soft, open-bodied, quick-curing type, suitable for early consumption.

Type I represents the class of cheese that is especially manufactured in Wisconsin, while, as a rule, type III represents the kind of cheese that is chiefly made in Michigan. The representatives of the sweet-curd type were taken from Iowa and Illinois, although this class is made to some extent in all sections.

The table herewith gives the location of the factories from which the different lots were secured, also the size and amount of cheese so purchased.

Origin of cheese and quantities used in experiments.

Origin and type.	Style.	Number.	Weight.
I.—*Export type.*			
Wisconsin:			*Pounds.*
Thos. Johnston, Boaz, Richland County	Flats	20	662
H. J. Noyes, Muscoda, Grant County	do	18	571
P. H. Kasper, Nicholson, Waupaca County	do	18	588
La Crosse Cheese and Butter Co., Alma, Buffalo County	Daisies	60	1,151
Do	Prints	40	400
II.—*Sweet-curd type.*			
Iowa:			
E. G. Hodges, Union, Hardin County	Flats	20	607
Illinois:			
J. B. Gilbert & Co., Sterling, Whiteside County	do	20	583
III.—*Soft, home-trade type.*			
Michigan:			
A. H. Barber & Co., Merrill, Saginaw County:			
I	Flats	9	287
II	do	9	287
III	do	29	924
IV	do	13	415

In having the cheese made at these various factories directions were given for the use of a uniform amount of rennet and salt. Color was left optional for each maker to follow his customary practice. The use of 3½ ounces of Hansen's rennet extract and 2½ pounds of salt per 1,000 pounds of milk was recommended in each case with the exception of the smaller cheeses (daisies and 10-pound prints), which were salted at the rate of 2¼ pounds per 1,000 pounds of milk. The cheese was made from September 26 to October 4. The condition of the milk was influenced in several instances by the fact that severe frosts had occurred in some sections, which injured the quality of the product. This was particularly true in the case of the Alma cheese, which was in consequence somewhat tainted. The milk from which the Iowa cheese was made was also reported as of inferior quality. The Michigan goods were too high in acid, and were cooked low, making a soft cheese, which was quick-curing and which kept poorly.

Where it was necessary to secure cheese from such a wide range of territory it was manifestly impossible to expect that the curing could be carried out as satisfactorily as if it had been done at or near the factories. The varying period of transit to which the cheese was subjected, with no especial temperature control, affected, of course, the initial stages of curing, but the conditions of the experiment prevented the carrying out of immediate installation of the cheese in the cold curing rooms, especially in the case of those made outside of Wisconsin, although the shipments were made in October, when the temperature range was moderate.

TEMPERATURES AT WHICH THE CHEESE WAS CURED.

The cheese was weighed and put in the respective rooms as soon as received at Waterloo. It was stored in boxes during the curing, as is the custom in the handling of cold-storage goods. The temperatures at which it was desired to hold the cheese for curing were 40°, 50°, and 60° F. These points were selected for the following reasons: In our previous experiments we had found that the character of the cheese cured at the lower temperatures (40° and 50°) was much better than that produced at 60°. Perhaps it would have been better for the purpose of the experiment if the cold-cured cheese could have been compared with the same make of cheese cured under the widely variable conditions which prevail in most factories, where often the maximum temperature is in the neighborhood of 80° F. and the fluctuation is 20° or more; but we have made this comparison with the very best conditions that obtain in factories provided with subearth ducts and other means of temperature control. In such cases a temperature of 60° can be maintained with a fair degree of constancy. The experiments, therefore, compare the cold-curing process with that of the best prevailing conditions.

The temperatures actually maintained varied only slightly from the chosen points, and in the two colder rooms were remarkably uniform. The 60° room was subject to somewhat wider fluctuations, but was much more uniform than is obtained in summer where no artificial refrigeration is practiced. The following table gives the average of all the observations made at regular intervals and the maximum and minimum observed throughout:

Temperature records.

	Cold rooms.		Normal temperature.
	Low.	Medium.	
	° F.	° F.	° F.
Average	36.8	46.9	58.5
Maximum	37.0	47.5	61.0
Minimum	35.0	45.0	57.0

The daily fluctuations were inconsequential, as can be seen by a series of graphs taken from the registering instrument.

DETAILS OF SCORING THE CHEESE.

It would have been advisable to have the cheese examined a considerable number of times by the commercial judges, but it was impossible to carry out this test so frequently. The tests were therefore arranged to come at those periods which would give the judges the

most accurate idea of the character of the cheese held at the different temperatures.

As a jury of commercial experts, representing the different markets, the following gentlemen were selected: C. A. White, of Fond du Lac, resident representative in Wisconsin of a leading dairy produce house of New York; T. B. Millar, of London, Ontario, a cheese expert and large buyer for the export trade, and John Kirkpatrick, a member of a leading produce firm of Chicago.

For the jury trials representative cheeses were taken from storage and shipped by refrigerator service to Chicago, where they were submitted to a thorough examination by the commercial judges. The first of these commercial scorings was made when it was found that the 60° product was ready for market. This test was made on January 6, 1903. Another test was made on March 23, when the cheese was about 7 months old.

It might at first thought seem preferable to have had the cheese sold in the open market and thus secured a strict commercial valuation on the product, but, as everyone knows, a considerable variation in quality may exist without an appreciable difference being made in the market price. Then, too, the inevitable fluctuations in the market price would render comparisons at different periods untrustworthy. To obviate these difficulties the cheese was scored on the basis of a standard price (13 cents). The fact that but few of the cheeses reached this standard should not be interpreted as indicating a poorer quality than the average market product, for the cheese was adjudged by the jury to be superior in quality; but the price was in part determined by the market appearance of the goods, which was somewhat inferior because of the fact that they had been box-cured and had received practically no care in curing, as the curing station was located at a distance from Madison.

The scores of the commercial jury were supplemented by a series of scores made by Mr. Baer which covered the entire history of the cheese from the time it was received until its final disposition. In this study it was possible to follow more closely the course of the ripening.

RESULTS OF EXPERIMENTS.

In presenting the data gathered in these experiments we have placed all of the detailed scores made by both the expert judges and Mr. Baer in an appendix. The following text is prepared from a study of these data, but only summaries are given in the text from which the deductions are made.

In outlining these results the data on shrinkage in weight during the experiment will first be given, followed by the serial scores made by Mr. Baer and the jury records obtained at the tests made when the cheese was three and five months old.

PART I.—SHRINKAGE OF CHEESE IN WEIGHT WHEN CURED AT DIFFERENT TEMPERATURES.

The losses in weight which cheese undergoes in the curing process is a matter of such practical importance that it is advisable when possible to accumulate data relating to it. This is all the more important in this connection because no studies have yet been reported on cold-cured cheese, and it was therefore deemed advisable to keep a record of the losses in weight so that the shrinkage at these lower temperatures might be compared with those which normally obtain at the best temperatures now employed. The average shrinkage under existing curing conditions in the majority of factories results in a loss of 5 to 7 per cent for the first thirty days, with a gradually diminishing rate for larger curing periods. This results in a heavy tax to the producer, and any factor which reduces these losses increases thereby the total receipts from the milk produced.

FACTORS INFLUENCING THE RATE OF LOSS.

There are a number of factors which modify the rate at which a cheese loses its water content during the course of ripening. The following factors are known to exert a more or less marked influence, although it is impossible to arrange them in order of their relative importance, as they are always interdependent: (1) Temperature of curing room; (2) relative humidity of air in curing room; (3) size and form of cheese; (4) moisture content of the cheese; (5) protection to external surface of the cheese.

The influence of temperature is closely connected with the relative humidity of the curing room; but, in addition to the effect which the higher temperatures exert on this factor, it should be observed that water evaporates more rapidly at a high than at a low temperature, even though the relative humidity remains the same. The more potent influence of temperature is, however, the effect which varying degrees of heat exert on the relative humidity of the atmosphere. A fall of 20° F. from ordinary air temperatures practically doubles the relative humidity, provided the point of saturation is not passed. As the average relative humidity of the air is generally over 50 per cent, it therefore follows, in cold-curing rooms supplied with outside air, the temperature of which is from 30° to 40° F. higher in summer than the inside temperatures, that the air of these rooms is practically saturated, thus greatly reducing the loss of moisture from the cheese.

So far as the cheese itself is concerned, the moisture of the room may be materially altered by the way in which the cheese is handled during the curing process. If the cheese is shelf-cured, as is the custom in most factories, the surrounding air more nearly approximates the average relative humidity of the entire room than is the case where

the goods are box-cured. In the latter case the air is more nearly saturated, as is shown by the greater liability to mold and rind-rot.

This point is well shown in a series of observations on the relative humidity of the air in a box containing a cheese placed directly therein from the press.

To show this the following observations were made: Wet and dry bulb thermometers (Hydrodeik) were placed in a Cheddar box with a 30-pound flat. An opening was made in the top and covered with glass so that observations could be made directly without opening the box. The apparatus was placed for a period in rooms at different temperatures and the observations recorded as follows:

Relative humidity of air surrounding box-cured versus shelf-cured cheese.

	Temperature range.	Relative humidity.	
		Room.	Cheese box.
	° *F.*	*Per cent.*	*Per cent.*
Room I	35–40	85–92	100
Room II	50–55	55–75	94
Room III	60–69	50–70	84–90

A factor which is frequently overlooked is the varying moisture content of the cheese. The more moisture there is left in the cheese the more rapid the evaporation. The varying moisture content of different types of cheese is determined by the temperature at which the curds are cooked, the time of exposure, and the acidity of the curd. A cheese in which the acidity is developed is materially drier than a sweet-curd cheese. Salt also has a tendency to diminish the water content. In the foregoing cases the cause of this diminution in moisture is due to the shrinking of the curd particles under the influence of these factors. An increase in fat lessens the drying of the curd. Much loss of moisture can also be prevented by coating the cheese with paraffin, a practice which is now coming into very general use for the prevention of mold and to lessen shrinkage in weight.

EXPERIMENTS IN SHRINKAGE OF COLD-CURED CHEESE.

In these experiments the first careful weighings were made when the cheese was received at the cold-storage plant in Waterloo. The cheese was shipped from the factories directly after it was removed from the press, but was in every case several days upon the road. In no instance was the interval between making and installing in cold-curing rooms less than five days, and it ranged from this up to seventeen days with one lot from Michigan, which was delayed in transit. During this period, which was in early October, the cheese was subjected to varying conditions of temperature and exposure. In a few

cases boxes were broken, and in other instances the cheese was delayed at points of transfer. It was impossible to obviate these difficulties, as the cheese was purchased at distant points in order to secure representation from a wide range of territory and from different types of cheese. This variation in initial drying changed, of course, the rate of loss when cheese was placed in cold-curing rooms, so that this factor must be taken into consideration in studying the data presented below.

The losses reported here cover those only which took place in the cheese after it had reached the cold-curing rooms, but careful records have been kept for the entire curing period; and these data, we believe, are of sufficient importance to warrant full consideration in this connection.

DETAILS OF WEIGHING.

The cheese was all weighed on counter scales, weighing accurately to fractions of an ounce. In order to check the accuracy of the weights, each cheese was weighed separately and the weight recorded; then the whole lot was weighed collectively. As these weights agreed within a few ounces, they show the accuracy of the weighings. For practical purposes it is desirable to know the losses which occur for stated periods. It was, however, impracticable for all of the cheese to be weighed at exactly the same intervals, as it was put in storage at different dates, but it was designed to secure at least three weighings for the first month of storage, two weighings for the second, and at about monthly intervals thereafter. If these data are charted, it is possible to deduce an estimated loss for any stated period, and in doing so we have selected the following intervals as being those concerning which data would be most frequently desired. For this purpose ten, twenty, thirty, sixty, ninety, etc., days have been selected.

CONDITIONS UNDER WHICH THE CHEESE WAS STORED.

In this work the attempt was made to hold the cheese at 40°, 50°, and 60° F. The actual temperatures secured averaged 36.8°, 46.9°, and 58.5° F. The variation in temperature in the two lower rooms was practically negligible, as it was only 2° to 2½°. The temperature of the 60° room oscillated somewhat more (4° F.), but was very much more uniform than ordinary factory curing rooms. (See figs. 1, 2, and 3 for samples of the thermometric record.)

Hygrometric data were not secured during the whole period, as it was at first thought that a saturated atmosphere would prevail where the cheese was box cured, but during the course of the experiments it was noted that the 50° cheese was not molding as much as was that at 40° and 60°. This fact could only be explained by the assumption that a less humid atmosphere was present in the case of the 50° room.

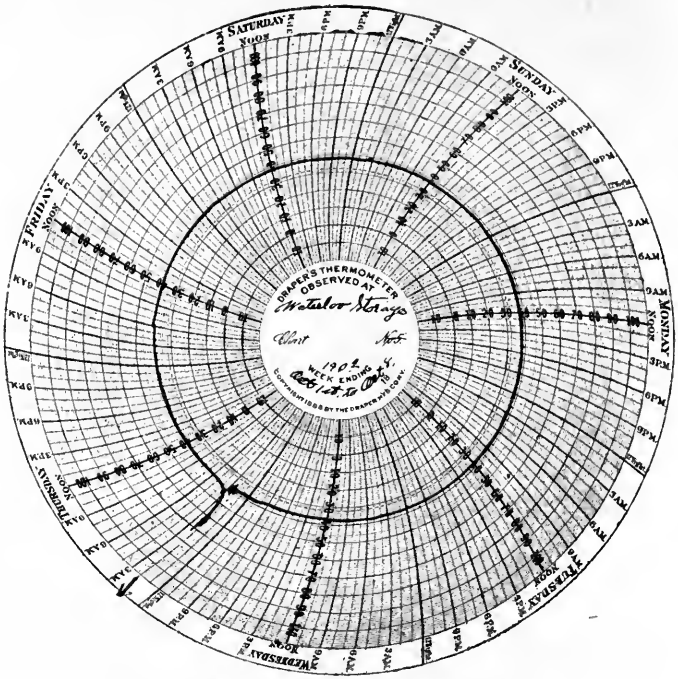


FIG. 1.—Temperature record of 40° curing room.

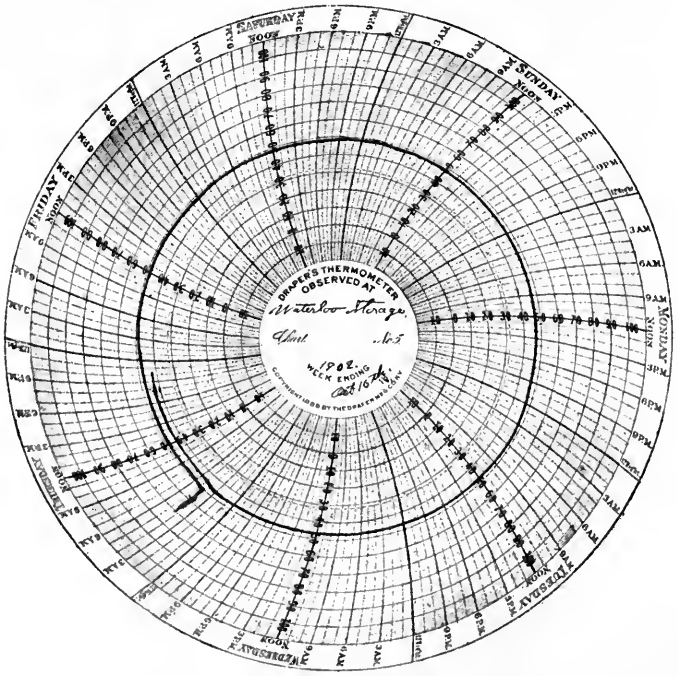


FIG. 2.—Temperature record of 50° curing room.

Observations at the end of the experiment showed a relative humidity in the different curing rooms as follows:

	Temperature.	Relative humidity.
	° F.	*Per cent.*
Room I..	37	92
Room II.	48	73
Room III	59	72

It will be observed in the figures later presented that the difference in rate of loss at 50° and 60° was higher toward the end of the experiment than in the earlier stages. This probably means that

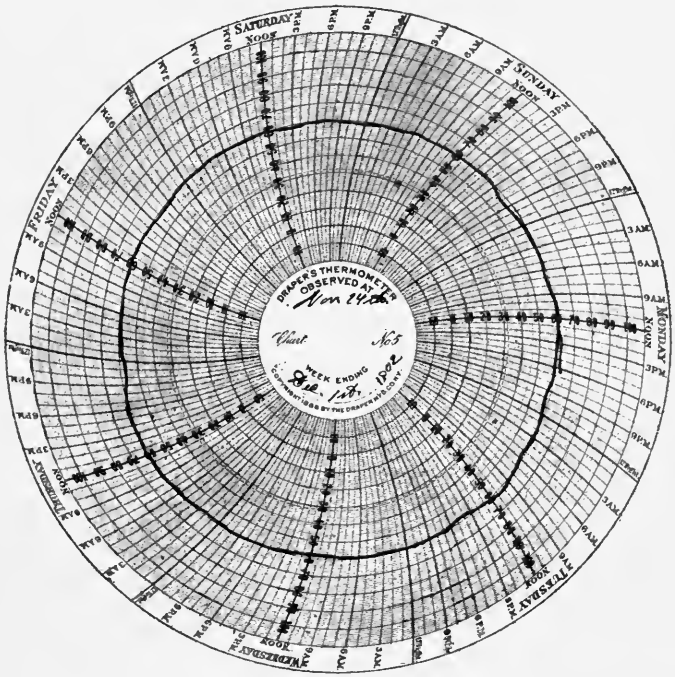


FIG. 3.—Temperature record of 60° curing room.

the relative humidity of room III was diminished at this time, bringing it down from a moister state to approximately the same humidity as the 50° room. If this was so, this would account for the lessened development of mold at 50°, as mold is very sensitive to hygrometric conditions.

DISCUSSION OF RESULTS.

As there are several factors which affect the rate of shrinkage which the cheese suffers in curing, it will be desirable to discuss the data collected under several heads. The conditions of the experiment

were such as to temperature that an especially favorable opportunity was had for the study of the influence which this factor exerts on the cheese. It is, of course, necessary in a study of this sort to have the cheeses uniform in size. The moisture contents of the cheese can not, of course, be made alike, but in this study the cheeses of the same type have been grouped together—that is, as firm Cheddars suitable for export and softer, moister cheese intended for home trade.

A. INFLUENCE OF TEMPERATURE ON SHRINKAGE.

To study the rate of loss of Cheddar cheese when kept at different temperatures, 129 flats were selected from nine different lots of cheese made by six different makers. These were exposed at three different temperatures, which averaged, respectively, 36.8°, 46.9°, and 58.5° F. In each of the tables herewith is given the number of cheeses which were subjected to stated weighings. It will be observed that much more data were collected on the lower temperatures than on the 60° lot. This was regarded necessary, as up to this time we have no published data on cheese cured at so low a temperature. The following tables give the actual loss in ounces of each lot of cheese, together with the percentage loss for each period observed.

In arranging these tables the lots of cheese that were similar in type are placed together. This fact gives much more weight to these figures than to those secured on the smaller lots.

For purposes of convenience the different lots of cheese are divided into three types, depending upon their character:

I. Firm-bodied cheese (export type), of Wisconsin.

II. Sweet-curd type, as represented by the Iowa and Illinois makes.

III. A very moist, soft type, suitable for home trade (Michigan).

Shrinkage of firm, typical Cheddar cheese (type I) cured at different temperatures.

LOT 1.—THOS. JOHNSTON, BOAZ, RICHLAND COUNTY, WIS.

Curing period (days).	Loss in weight at different periods of storage.					
	At 40° F.		At 50° F.		At 60° F.	
	Ounces.	*Per cent.*	*Ounces.*	*Per cent.*	*Ounces.*	*Per cent.*
10					17	1.26
17			31	1.16	28	1.86
21	17	0.365				
26			50	1.88		
51	37	.796	68	2.55	44	2.83
88	51	1.09	92	3.15	58	3.73
112	54	1.16	100	3.76	65	4.19
160	58	1.18	123	4.55	96	6.13
Weights of cheeses when received	299 lbs. 6 ozs.		166 lbs. 4 ozs.		97 lbs. 1 oz.	
Number of cheeses weighed	9		5		3	

Shrinkage of firm, typical Cheddar cheese (type I), etc.—Continued.

LOT 2.—H. J. NOYES, MUSCODA, GRANT COUNTY, WIS.

Curing period (days).	Loss in weight at different periods of storage.					
	At 40° F.		At 58° F.		At 60° F.	
	Ounces.	*Per cent.*	*Ounces.*	*Per cent.*	*Ounces.*	*Per cent.*
10	.....	.....	.....	.....	14	0.912
16	.....	.....	16	1.07	26	1.69
19	17	0.374	.....	.....	.....	.....
24	.....	.....	28	1.87	.....	.....
50	35	.77	39	2.61	41	2.67
86	44	.994	63	4.22	49	3.13
110	44	.994	71	4.75	56	3.65
158	50	1.12	82	5.49	78	5.09
Weights of cheeses when received	279 lbs. 12 ozs.		93 lbs. 5 ozs.		95 lbs. 14 ozs.	
Number of cheeses weighed	9		3		3	

LOT 3.—P. H. KASPER, NICHOLSON, WAUPACA COUNTY, WIS.

	Ounces.	*Per cent.*	*Ounces.*	*Per cent.*	*Ounces.*	*Per cent.*
10	18	0.383	13	0.845	11	0.716
20	.....	.....	25	1.62	22	1.43
26	34	.724	.....	.....	.....	.....
37	.....	.....	34	2.21	.....	.....
41	.....	.....	.....	.....	38	2.47
74	40	.852	50	3.25	.....	.....
87	.....	.....	.....	.....	56	3.64
97	45	.951	52	3.38	.....	.....
100	.....	.....	.....	.....	60	3.90
145	.....	.....	68	4.42	78	5.07
163	70	1.46	78	5.06	84	5.46
Weights of cheeses when received	293 lbs. 8 ozs.		96 lbs. 2 ozs.		96 lbs. 1 oz.	
Number of cheeses weighed	9		3		3	

As these three makes of cheese agree quite closely in type, a composite diagram made from the data collected will indicate more nearly the average results which may be expected than where they are considered separately. The actual losses observed in the three foregoing lots of Wisconsin cheese were first charted individually and from these an average curve constructed, which is represented in figure 4. In this and following figures the losses are shown for a period of ninety days only, so that the figures would be on the same scale.

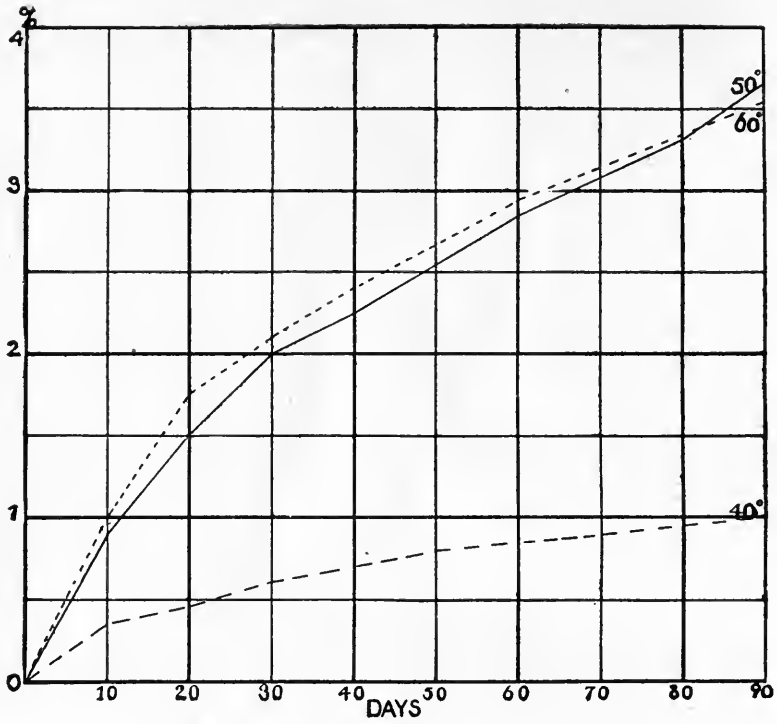


FIG. 4.—Weight losses—type I, cured at different temperatures.

Shrinkage of sweet-curd cheese (type II) cured at different temperatures.

LOT 1.—E. J. HODGES, UNION, IOWA.

Curing period (days).	Loss in weight at different periods of storage.					
	At 40° F.		At 50° F.		At 60° F.	
	Ounces.	*Per cent.*	*Ounces.*	*Per cent.*	*Ounces.*	*Per cent.*
7	35	0.774	23	0.933	12	0.852
17	.....	.....	.....	.....	22	1.56
20	.....	.....	35	1.42	.....	.....
34	51	1.13	.....	.....	32	2.27
37	.....	.....	63	2.55	.....	.....
71	55	1.21	.....	.....	61	4.33
74	.....	.....	76	3.07	.....	.....
94	69	1.59	86	3.47	66	4.68
145	.....	.....	103	4.16	78	5.54
163	85	1.88	.....	.....	.....	.....
Weight of cheeses when received	282 lbs. 7 ozs.		154 lbs. 7 ozs.		88 lbs. 1 oz.	
Number of cheeses weighed	9		5		3	

Shrinkage of sweet-curd cheese (type II) cured at different temperatures—Continued.

LOT 2.—J. B. GILBERT & CO., STERLING, ILL.

Curing period (days).	Loss in weight at different periods of storage.					
	At 40° F.		At 50° F.		At 60° F.	
	Ounces.	*Per cent.*	*Ounces.*	*Per cent.*	*Ounces.*	*Per cent.*
10	22	0.533	26	1.11	15	1.08
20	.....	.....	42	1.80	26	1.88
26	34	.821	.....	.....	.....	.....
37	.....	.....	58	2.41	40	2.89
74	50	1.21	83	3.56	56	4.13
97	62	1.50	92	3.94	.....	.....
100	.....	.....	.....	.....	63	4.56
145	.....	.....	110	4.71	73	5.29
163	74	1.79	.....	.....	.....	.....
Weight of cheeses when received	258 lbs.		145 lbs. 13 ozs.		86 lbs. 4 ozs.	
Number of cheeses weighed	9		5		3	

A composite curve of this type of cheese was made in a similar manner to that noted in type I (fig. 4), and is represented in figure 5.

Shrinkage of soft, moist, home-trade cheese (type III) cured at different temperatures.

LOT 1.—A. H. BARBER & CO., MERRILL, MICH.

Curing period (days).	Loss in weight at different periods of storage.					
	At 40° F.		At 50° F.		At 60° F.	
	Ounces.	*Per cent.*	*Ounces.*	*Per cent.*	*Ounces.*	*Per cent.*
10	6	0.30	6	1.15	5	1.05
20	.....	.....	10	1.92	7	1.47
26	10	.50	.....	.....	.....	.....
37	.....	.....	12	2.30	.....	.....
41	.....	.....	.....	.....	10	2.10
74	14	.70	16	3.07	15	3.15
100	20	1.00	18	3.46	19	3.99
145	.....	.....	21	4.38	28	5.88
Weight of cheeses when received	125 lbs. 6 ozs.		32 lbs. 8 ozs.		29 lbs. 12 ozs.	
Number of cheeses weighed	4		1		1	

Shrinkage of soft, moist, home-trade cheese (type III), etc.—Continued.

LOT 2.—A. H. BARBER & CO., MERRILL, MICH.

Curing period (days).	Loss in weight at different periods of storage.					
	At 40° F.		At 50° F.		At 60° F.	
	Ounces.	*Per cent.*	*Ounces.*	*Per cent.*	*Ounces.*	*Per cent.*
4	2	0.10	.....	.....	.....	.....
10	.....	.....	4	0.837	4	0.840
20	.....	.....	8	1.67	7	1.47
26	13	.65	.....	.....	.....	.....
37	.....	.....	11	2.30	.....	.....
41	.....	.....	.....	.....	10	2.10
74	17	.85	14	2.92	16	3.36
100	28	1.40	18	3.76	20	4.20
145	.....	.....	21	4.38	30	6.30
Weight of cheeses when received	121 lbs. 11 ozs.		29 lbs. 14 ozs.		29 lbs. 12 ozs.	
Number of cheeses weighed	4		1		1	

LOT 3.—A. H. BARBER & CO., MERRILL, MICH.

	Ounces.	*Per cent.*	*Ounces.*	*Per cent.*	*Ounces.*	*Per cent.*
10	42	0.538	32	0.88	17	0.814
20	.....	.....	76	2.08	28	1.34
37	73	.935	102	2.79	44	2.10
74	82	1.05	124	3.39	68	3.25
100	95	1.21	133	3.67	73	3.49
Weight of cheeses when received	487 lbs. 14 ozs.		228 lbs.		13 lbs. 7 ozs.	
Number of cheeses weighed	15		7		4	

LOT 4.—A. H. BARBER & CO., MERRILL, MICH.

	Ounces.	*Per cent.*	*Ounces.*	*Per cent.*	*Ounces.*	*Per cent.*
7	23	0.676	9	0.928	6	1.24
17	.....	.....	.....	.....	11	2.28
20	.....	.....	17	1.75	.....	.....
34	39	1.14	23	2.37	18	3.73
71	47	1.37	28	2.88	29	6.02
97	55	1.62	38	3.92	32	6.64
145	.....	.....	.....	.....	39	8.09
Weight of cheeses when received	219 lbs. 7 ozs.		60 lbs. 9 ozs.		30 lbs. 9 ozs.	
Number of cheeses weighed	7		2		1	

In the four preceding lots of cheese considerable difference in rate of loss will be noticed. This is explained, when it is considered that these lots were exposed during transit period to higher temperatures

for varying periods of time, as follows: Lot 1, seventeen days; lot 2, fourteen; lot 3, twelve; and lot 4, seven days.

Figure 6 shows a composite curve of the Michigan cheese, which was made in a similar manner to those shown in figures 4 and 5.

GENERAL SUMMARY OF LOSSES AT DIFFERENT TEMPERATURES.

In figures 4, 5, and 6 the average curves showing losses of the different types of Cheddar cheese are shown. Frequently the cheese

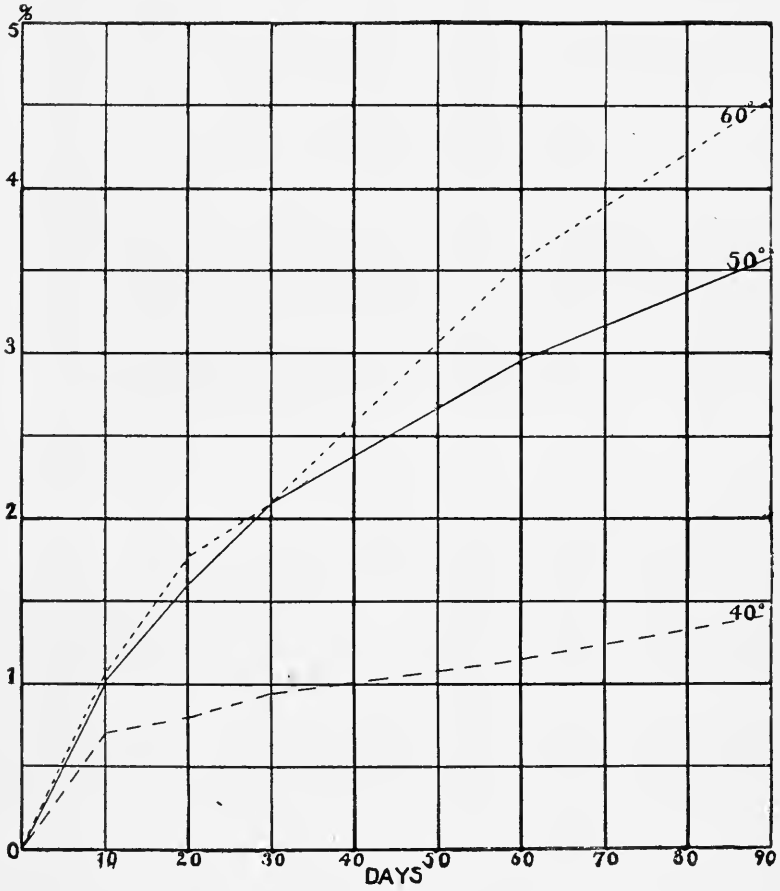


FIG. 5.—Weight losses—type II, cured at different temperatures.

maker wishes to know what these losses would be for stated intervals at different temperatures. With the data at our command it is impossible to answer definitely this question, because of the varying conditions which surrounded the cheese during the transit period, but in the table below the losses which occurred after the cheeses were installed in the respective curing rooms are presented for consideration. In this table the average losses for ten days or multiples thereof

are given. In constructing this table the data for each lot of cheese were first charted. From the curves so obtained the losses of each lot for the periods of ten, twenty, thirty, sixty, and ninety days were

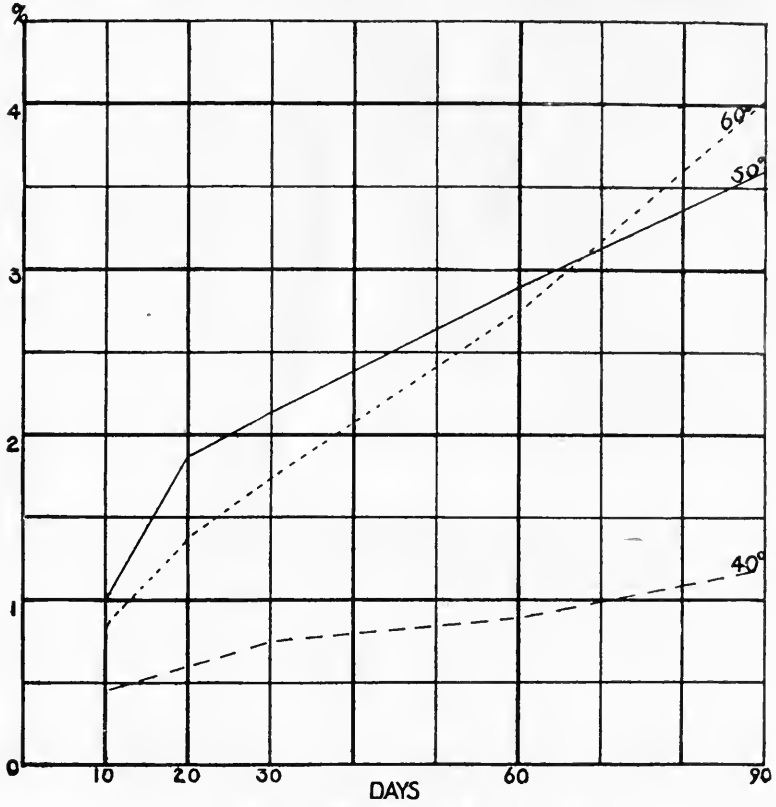


FIG. 6.—Weight losses—type III. Michigan cheese.

taken from the above charts by observation. An average of these losses for each type of cheese is given in the following table:

Losses at different periods in cheese cured at different temperatures.

Days.	Type I (typical Cheddar).			Type II (sweet-curd).			Type III (soft).		
	27 cheeses tested at 40°.	11 cheeses tested at 50°.	9 cheeses tested at 60°.	9 cheeses tested at 40°.	5 cheeses tested at 50°.	5 cheeses tested at 60°.	30 cheeses tested at 40°.	11 cheeses tested at 50°.	7 cheeses tested at 60°.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
10.....	0.38	0.92	0.96	0.69	1.02	1.05	0.49	0.92	0.85
20.....	.44	1.48	1.74	.82	1.60	1.77	.64	1.89	1.39
30.....	.58	2.00	2.05	.96	2.10	2.29	.84	2.35	1.75
60.....	.83	2.87	2.95	1.15	2.97	3.67	.98	2.98	2.77
90.....	1.00	3.64	3.57	1.42	3.60	4.47	1.21	3.55	4.02

As the number of cheeses of the different types cured at the various temperatures were not the same, the percentage losses given in the above table for the varying periods noted are therefore not entitled to equal weight. The smallest number of cheeses were those exposed at

60°, while nearly 60 per cent of the entire lot were kept at 40°. This gives much greater weight to the figures presented in the 40° series.

In the table it will be observed that there are some apparent discrepancies, especially in the case of the 50° and 60° lots of type III. These discrepancies are undoubtedly explained by the fact that this type of cheese, which was the moistest of the whole lot in the beginning, lost more during the longer transit period, and hence the evaporation was less than in other types after being placed in cold storage.

(1) The losses sustained by the different lots were very much less at 40° F. than at either of the other two temperatures. For a ninety-day period the losses of the 40° cheese ranged from 1 to 1.4 per cent, while the 50° and 60° product shrunk from 3.4 to 4.5 per cent for the same time. In other words, by the use of the lower temperature for curing practically two-thirds of the losses which occurred at the temperatures of 50° and 60° were prevented. If these results are compared with what happens under ordinary factory conditions, the loss at these low temperatures for a period of ninety days (the minimum curing period recommended) will not be more than one-fourth of that which obtains under average factory conditions when the cheeses are held for a period of about twenty days. The saving for any such factory making 500 pounds of cheese daily would amount to at least 15 pounds of cheese (or $1.50) per day as an average for the season, and considerably more than this for cheese made during hot weather. This saving in itself would go far toward meeting the extra expense of lower temperature curing, even if the product was no better than that cured at higher temperatures.

(2) The differences between the cheese cured at 50° and 60° are not so marked as between 50° and 40°. It is quite probable, as before mentioned, that the 50° room was somewhat drier than the 60° (as shown by the lessened mold growth), and hence the rate of loss was abnormally increased in this room. This would tend to bring the two curves nearer together.

(3) If the firm Wisconsin type is compared with the softer variety, as shown in types II and III, it appears that the losses are considerably less, especially at the higher temperatures, although this difference is not so observable at 40°.

(4) The above data presented show a marked saving in losses where the cheese was cold cured, but in these experiments it must be remembered that the cheese was subjected to higher temperatures during transit, and hence dried out somewhat more than would have occurred if put in storage as soon as removed from the press; also, that this cheese was box-cured, and therefore under conditions which prevented rapid evaporation. Under other conditions the losses would have been greater than represented here, and the difference in the rate of loss between the different lots wider than reported above. This would still further increase the saving.

B. INFLUENCE OF SIZE AND FORM OF CHEESE ON SHRINKAGE.

In order to study the influence of size of package on shrinkage during curing, lots of two different sizes were purchased from the same source. These two sizes were the customary daisy type, 13 inches in diameter and 3½ inches high, weighing about 20 pounds apiece, and the newer type of print cheese, put up in 10-pound blocks (10 by 10 by 2⅝ inches). These cheeses were of the usual Wisconsin Cheddar type, although a little firmer than the Wisconsin flats used in these experiments. On account of this difference in type, it is impossible to compare these cheeses directly with the larger 30-pound size.

In the following tables are presented the actual and percentage losses which were noted in the two lots of cheese (daisies and prints) which were purchased from the La Crosse Cheese and Butter Company, of La Crosse, Wis.:

Shrinkage of different-sized cheeses cured at different temperatures.

LOT 1.—PRINTS (10 POUNDS).

Curing period (days).	Loss in weight at different periods of storage.					
	At 40° F.		At 50° F.		At 60° F.	
	Ounces.	*Per cent.*	*Ounces.*	*Per cent.*	*Ounces.*	*Per cent.*
7	.....	.....	1	0.62	2	1.23
10	3	0.371	.....	.....	.....	.....
16	.....	.....	3	1.82	.....	.....
24	.....	.....	.....	.....	4	2.46
41	7	.865	5	3.1	8	4.92
78	11	1.35	9	5.59	14	8.64
100	14	1.73	10	6.2	16	9.88
167	21	2.61	12	7.45	18	11.11
Weights of cheeses when received	50 lbs. 8 ozs.		10 lbs. 1 oz.		10 lbs. 2 ozs.	
Number of cheeses weighed	5		1		1	

LOT 2.—DAISIES (20 POUNDS).

	Ounces.	*Per cent.*	*Ounces.*	*Per cent.*	*Ounces.*	*Per cent.*
7	.....	.....	35	0.673	25	1.14
16	38	0.527	72	1.38	.....	.....
24	.....	.....	.....	.....	41	1.96
30	66	.916	.....	.....	.....	.....
41	.....	.....	103	1.98	65	3.11
78	90	1.25	128	2.46	89	4.26
100	101	1.40	134	2.58	97	4.64
149	136	1.89	148	2.85	118	5.65
Weights of cheeses when received	449 lbs. 15 ozs.		325 lbs. 8 ozs.		130 lbs. 9 ozs.	
Number of cheeses weighed	24		17		7	

In figures 7 and 8 are represented, graphically, the losses observed in the smaller sizes of cheeses (10 and 20 pound varieties). It will be noted that these losses at the different temperatures are greater as the temperature increases, and that the differences between the various temperatures are more marked as the relative size of the cheese diminishes.

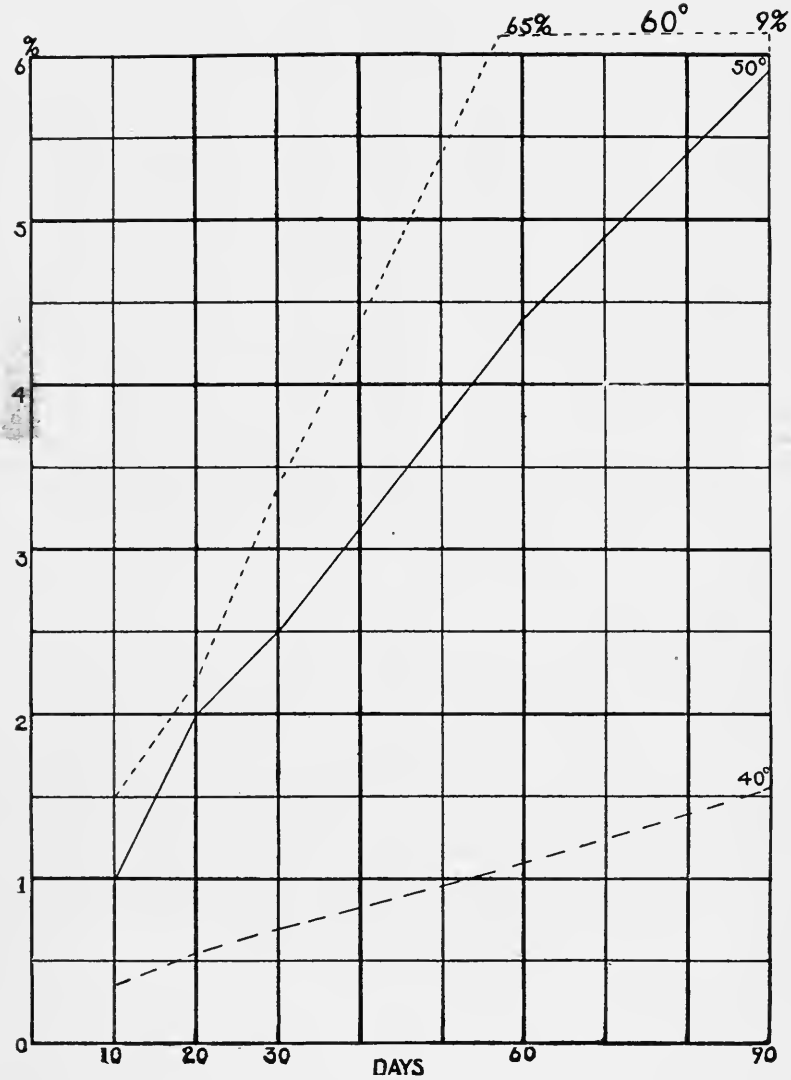


FIG. 7.—Weight losses. 10-pound prints.

In order that a comparison may be made between different sizes of cheeses at the same temperatures, and the losses at these respective temperatures compared with each other, the foregoing data are rearranged in figures 9, 10, and 11, so as to show the rate of losses of the different sizes of cheeses at the different temperatures.

From these curves it is evident that at 40° (fig. 9) the loss was practically the same in both sizes of the cheeses. This is probably because the relative humidity at this temperature was practically 100 per cent, and therefore in a saturated atmosphere the rate of evaporation would be reduced to a minimum, regardless of the size of the cheese.

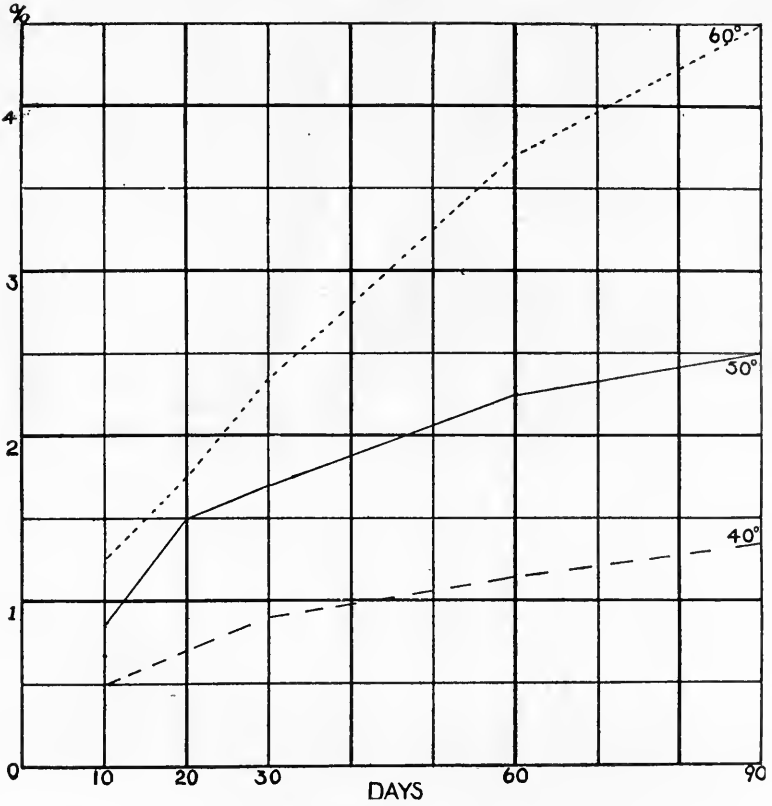


FIG. 8.—Weight losses. 20-pound "Daisies."

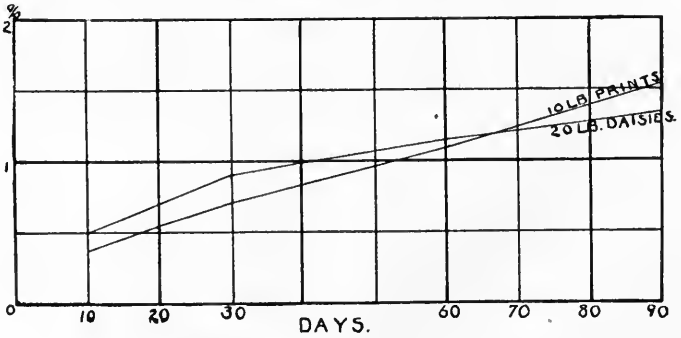


FIG. 9.—Weight losses. Small cheeses. Cured at 40° F.

It must be remembered that the entire loss in weight during the curing of cheese is not due to evaporation. A cheese in curing is

constantly breathing out carbon dioxide the same as any living organism, due to the development of microorganisms (bacterial growth within the cheese as well as molds on surface). Aside from these biological factors, it has recently been shown by Van Slyke and Hart[a] that profound proteolytic decompositions also give rise to an appreciable amount of CO_2. With cheese at 60° F., in which external mold growth was suppressed, they found a loss of approximately one-

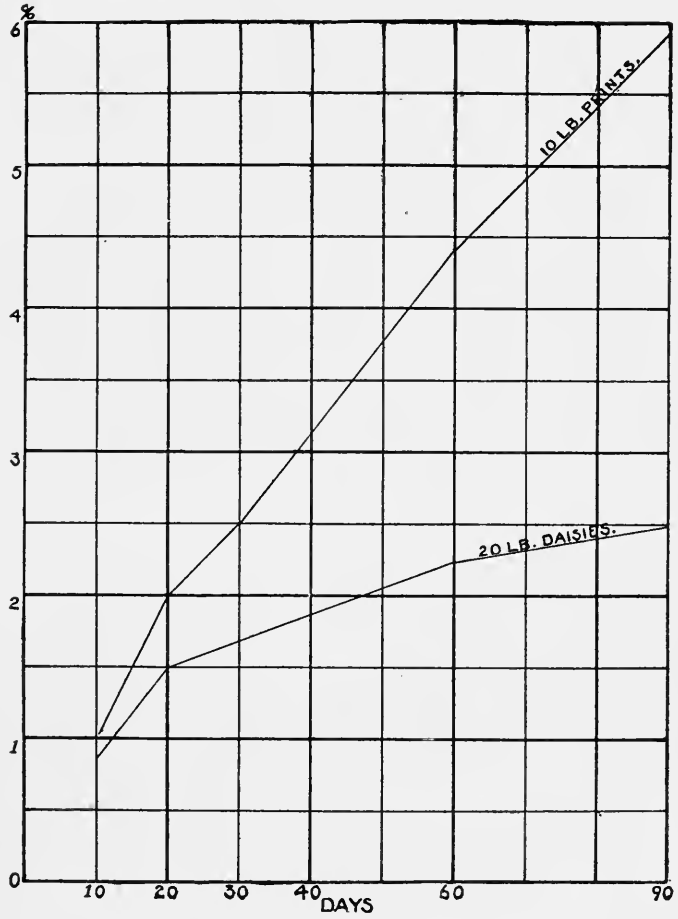


FIG. 10.—Weight losses. Small cheeses. Cured at 50° F.

fourth of 1 per cent in ninety days. In our cold-cured cheese, copious mold development occurred, and hence the losses of carbon from the cheese due to this growth would be considerably greater than if no such growth occurred. With the nearly uniform rate of shrinkage shown in these cold-cured cheeses, regardless of size, it is quite problematical whether this loss in weight may not be chiefly due to the operation of the foregoing factors. If this is so, we may consider

[a] Bul. No. 231, New York Agricultural Experiment Station, p. 36.

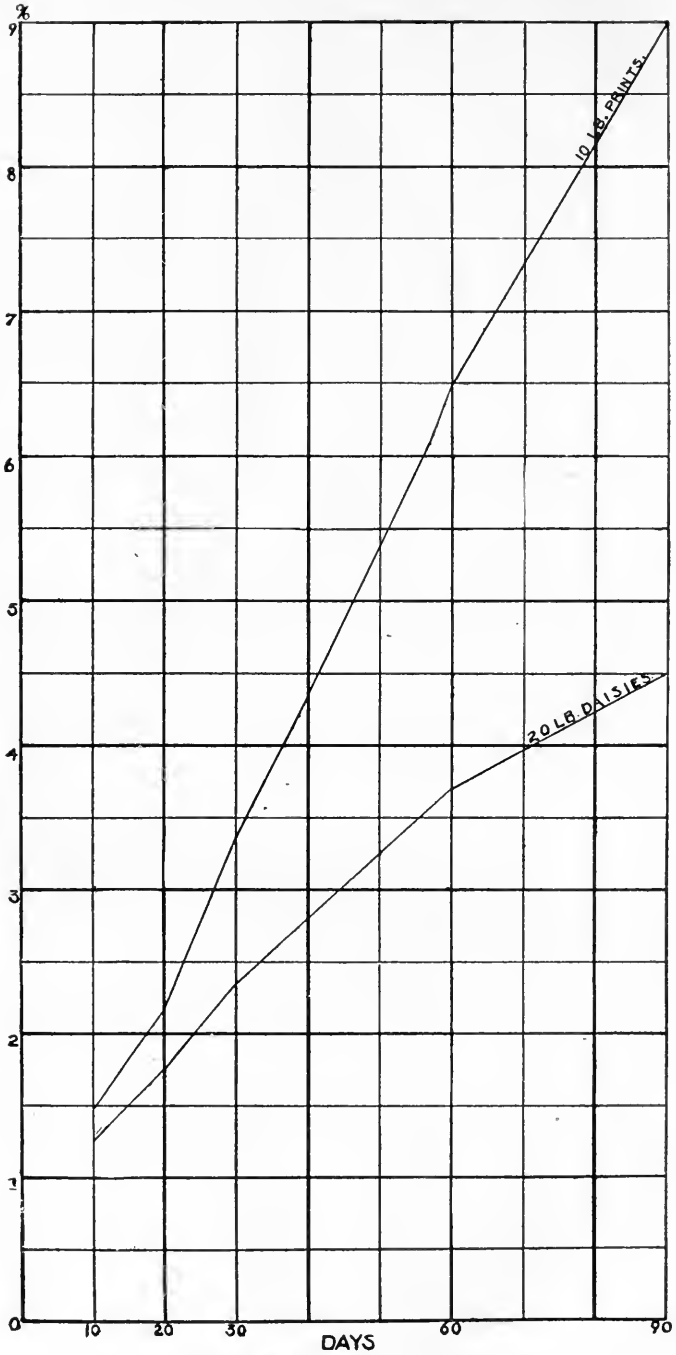


FIG. 11.—Weight losses. Small cheeses. Cured at 60° F.

NOTE.—Figures 9, 10, and 11 should be compared as showing the relative loss of cheeses of different sizes.

such losses as absolutely unavoidable under normal conditions, for the action of microorganisms which can not be suppressed will inevitably result in the production of some volatile products.

At the temperatures of 50° and 60°, where the relative humidity was below saturation, the factor of evaporation is apparent and is inversely related to the size of the cheese. From a practical point of view, it is worth noting that the losses in both sizes of cheeses cured at 60° are approximately 50 per cent more than they are in the cheese ripened at 50° F. (See Figs. 10 and 11.)

C. INFLUENCE OF PARAFFINING CHEESE ON SHRINKAGE DURING CURING.

Within the last few years the custom of coating the cheese with an impervious layer has been suggested, with the object mainly of preventing the development of mold. For this purpose paraffin has been found to be the most suitable agent. The application of such a layer to the cheese not only prevents the growth of mold spores by excluding the air, but materially retards the rate at which the cheese loses its moisture. Paraffined cheese then dries out much more slowly than the untreated product, and the application of this method is of particular service in the handling of the smaller types of cheeses, which have a relatively larger superficial area exposed to the air.

To study the effect of this method of treatment at different temperatures, a number of the smaller sizes of cheeses (daisies and 10-pound prints) were taken from the same make and part of them covered with paraffin. These were divided into three lots and placed in the different curing rooms, where they were held for a period of several months.

In the following table are recorded the data as to the percentage loss in both the paraffined and unparaffined (control) lots:

Shrinkage in paraffined and unparaffined cheese cured at different temperatures.

10-POUND PRINT CHEESE.

Curing period (days).	Loss in weight for different periods of storage.					
	At 40° F.		At 50° F.		At 60° F.	
	Unparaffined.	Paraffined.	Unparaffined.	Paraffined.	Unparaffined.	Paraffined.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
7	.....	.....	0.62	0.24	1.23	0.603
10	0.37	0.495	.....	.....	.....	.....
16	.....	.....	1.82	.84	.....	.....
24	.....	.....	.....	.....	2.46	1.8
41	.865	1.06	3.1	1.45	4.92	2.77
77	1.35	1.48	5.6	2.9	8.64	3.01
100	1.73	1.88	6.2	3.5	9.88	3.62
Number of cheeses tested	5	17	1	5	1	5

Shrinkage in paraffined and unparaffined cheese cured at different temperatures—Cont'd.

20-POUND DAISIES.

Curing period (days).	Loss in weight for different periods of storage.					
	At 40° F.		At 50° F.		At 60° F.	
	Unparaffined.	Paraffined.	Unparaffined.	Paraffined.	Unparaffined.	Paraffined.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
7			0.673		1.14	0.317
14	0.527	0.466				
16			1.38	0.609		
24					1.96	1.58
30	.916	1.10				
41			1.98	.914	3.11	2.54
77	1.25	1.71	2.46	1.65	4.26	3.17
100	1.40		2.58	2.0	4.64	3.49
Number of cheeses tested	24	4	17	1	7	1

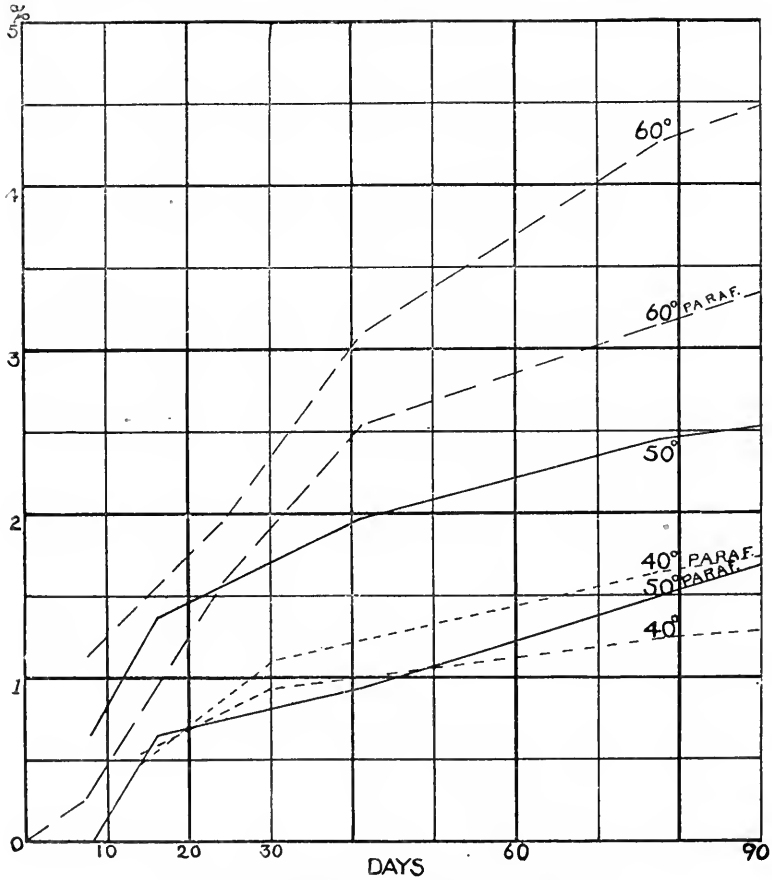


FIG. 12.—Weight losses. 20-pound Daisies. Paraffined.

In order to permit a more ready comparison of the above data, the same are presented in graphical form in figures 12 and 13. At 60° F. the application of paraffin resulted in reducing the losses to less than one-half of that which occurred in the unparaffined lot. This difference is naturally more observable in the smaller-sized cheeses (prints). At

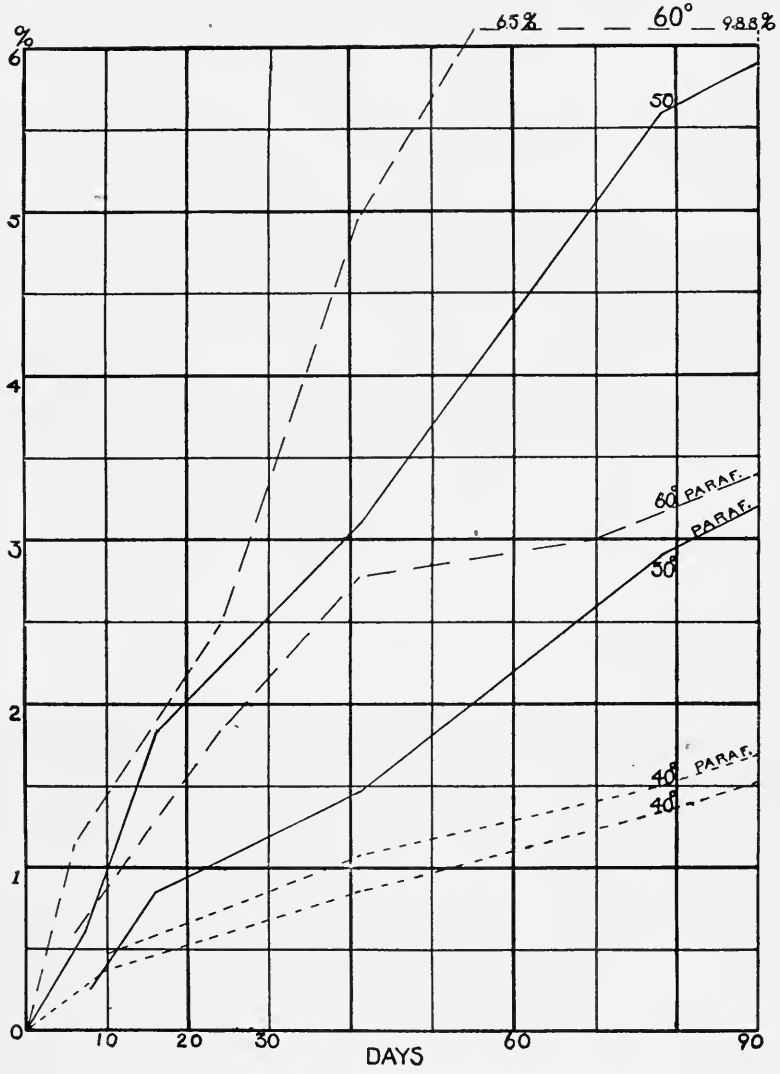


FIG. 13.—Weight losses. 10-pound prints. Paraffined.

50° this ratio was slightly diminished, but was in the same general direction. At 40° a peculiarity is observable in both the print and the daisy size, in that the paraffined cheese lost a trifle more than the unparaffined lot. We do not think this apparent paradox can be explained on the basis of errors in weighing, as there were five

unparaffined and seventeen paraffined print cheeses and twenty-four unparaffined and four paraffined 20-pound cheeses in these experiments. Also the weighings of these cheeses were made at frequent intervals and in every case the same relation was observed. Further experiments are in progress to test the accuracy of these observations.

In the paraffined cheese at 40° the losses were reduced practically to a minimum, as was also the case with the unparaffined at this temperature. As evaporation would certainly be lessened in the paraffined lot, the uniformity of loss between these and the unparaffined still further substantiates the view advanced earlier that these losses are not so much due to shrinkage from evaporation as they are to metabolic activities of organisms and possibly chemical transformations within the cheese.

PART II.—EFFECT OF TEMPERATURE ON QUALITY OF CHEESE.

A. COURSE OF CURING AT DIFFERENT TEMPERATURES.

Originally it was planned to have the cheese judged by commercial experts, but it was found impossible to arrange for a sufficiently large number of such tests to closely follow the progressive changes which occurred in the course of the ripening of the cheese. Hence, in addition to the examinations made by the jury of commercial experts, the cheese was carefully scored at Waterloo by Mr. Baer at frequent intervals. The full details of these examinations, which include numerical and descriptive scores, as well as the intrinsic value of the cheese at the different periods when it was examined, are presented in the appendix (p. 57.)

Course of Ripening in Type I.

This type was represented by four different lots of Wisconsin cheese. All of them were well-cooked, firm-bodied, slow-ripening cheese that may be regarded as typical Cheddars. In one case the milk from which the cheese was made was evidently tainted, as the cheese was slightly off at the outset.

The results of these periodical scores by Mr. Baer show that good cheese was produced at all temperatures in the first three lots. Naturally that cured at 60° developed more rapidly than the goods cured at lower temperatures, but it should be noticed that even at this temperature some of the firm-textured cheese went off in five months. At 50° and 40° the cheese was about six weeks to two months behind the 60° in development, but in time it reached as high as the 60° lot, and generally of a better quality, and kept this maximum condition much longer than the 60°. This enhanced keeping quality was more pronounced at 40° than at 50°.

In the lot made from tainted milk (La Crosse, p. 58) the imperfect condition was pronounced at all temperatures, but was more prominent at 60° than below.

In studying the detailed scores by Mr. Baer, presented in the appendix, it is possible to combine the numerical scores of the four different lots of Wisconsin cheese belonging to the same type and so obtain a set of averages, as to flavor, texture, and price, which indicate clearly the progress of the curing of these various lots at the different temperatures. In the following table these summaries are included:

Summary of scores and values of cheese in type I (firm export type).

Age (months).	Flavor (standard 45).			Texture (standard 30).			Price (standard 13 cents).		
	40°.	50°.	60°.	40°.	50°.	60°.	40°.	50°.	60°.
1	33.3	34.3	35.8	23.3	22.3	24.3	.....	.....	.....
2	37	38.3	39	26	25.3	26.8	10	10.5	10.8
3	41.5	42.3	42.3	28.6	28.5	29	11.81	12.4	12.4
5	43	41	39.5	29.3	29	27.5	12.69	12	11.44
8	43.8	.....	.....	29	.....	.....	12.75	.....	.....

Flavor.—The variation in flavor observed at the different temperatures is more marked than any other characteristic. This range in flavor is also shown graphically in figure 14. From this it appears

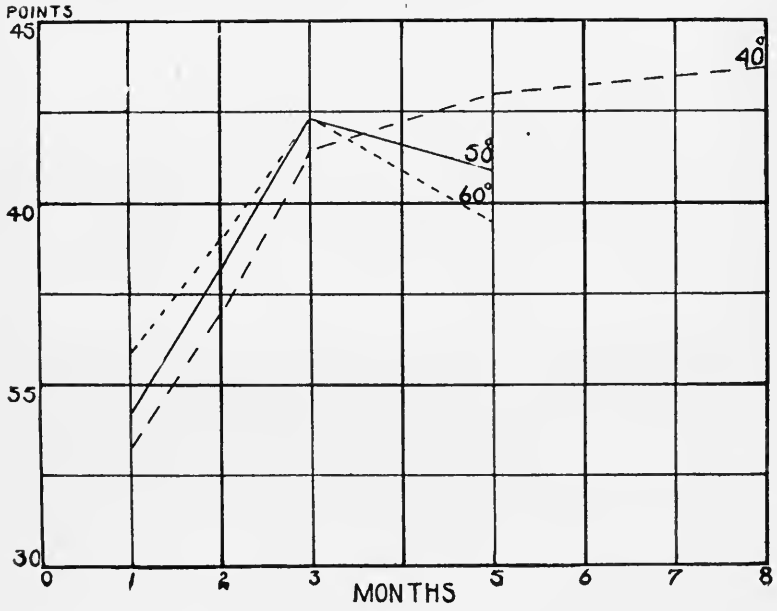


FIG. 14.—Flavor for type I.

that at the higher temperatures the flavor is more developed during the earlier ripening stages, but as the cheese increases in age the quality

of the flavor at the higher temperatures deteriorates more rapidly than in the cold-cured goods. At the end of five months the 40° was still improving, and even at this time was higher than at any period with the 50° and 60°. At present writing (eight months), the cold-cured cheese is still of excellent quality, and shows no signs of deterioration.

Texture.—The texture of the cheese followed quite closely a development similar to that noted under "Flavor." In the earlier stages the 60° had the highest score, but it reached its maximum in three months, while the 50° and 40° continued to improve up to the end of the test, and was higher in the 40° at this time than at any time in the 60°. This condition is shown in figure 15.

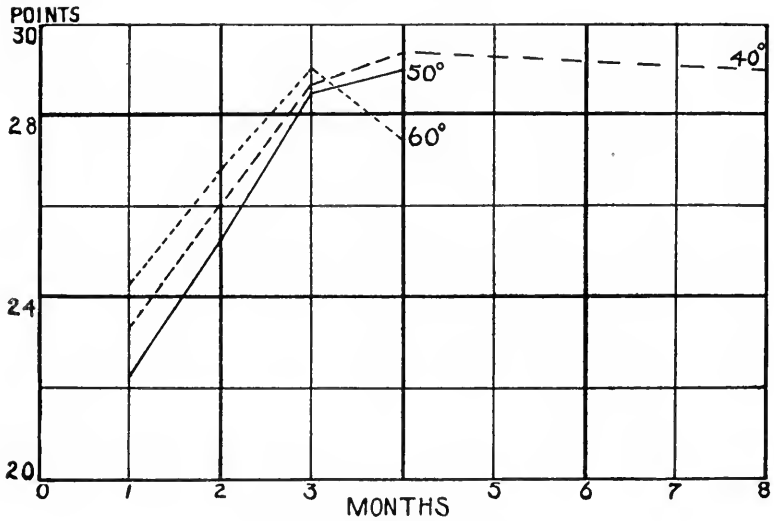


FIG. 15.—Texture for type I.

Price.—Figure 16 presents the range in intrinsic value throughout the test. The improved condition with reference to flavor and texture naturally reappears in this commercial standard, in which the 40° cheese, while developing somewhat more slowly, soon passes both the 50° and 60°, and continues to improve while the two latter decline toward the end of the experiment.

The beneficial effect of cold-curing on this firm type of cheese is strikingly apparent from the above data and diagrams. Not only was this cold-cured cheese free from any bitterness or taint incident to the curing process, but it was much improved in texture, as is evident from Plate I, which shows the appearance of cheese made from the same vat but cured at approximately 40°, 50°, and 60° F. When the cheese is cold cured the body is much closer, as the curd particles are subject to more pronounced shrinkage at higher temperatures, which causes the formation of these irregular, ragged cracks. This is per-

Three Cheese Sections—Type I.

Cheese at top cured at 40°, in middle at 50°, and at bottom at 60°.

Two Vertical Cheese Sections—Type I.

Cheese cured at 40° on left and cheese cured at 60° on right.

haps rendered more obvious in Plates II and III, in which the cheese cured at 40° and 60° are shown. When it is remembered that the results ordinarily obtained in factory curing are not anything like as satisfactory as those shown in the cheese cured at 60°, the improvement in quality, as shown by the texture of the cheese cured by the cold-curing process over that now in vogue, is emphasized still more.

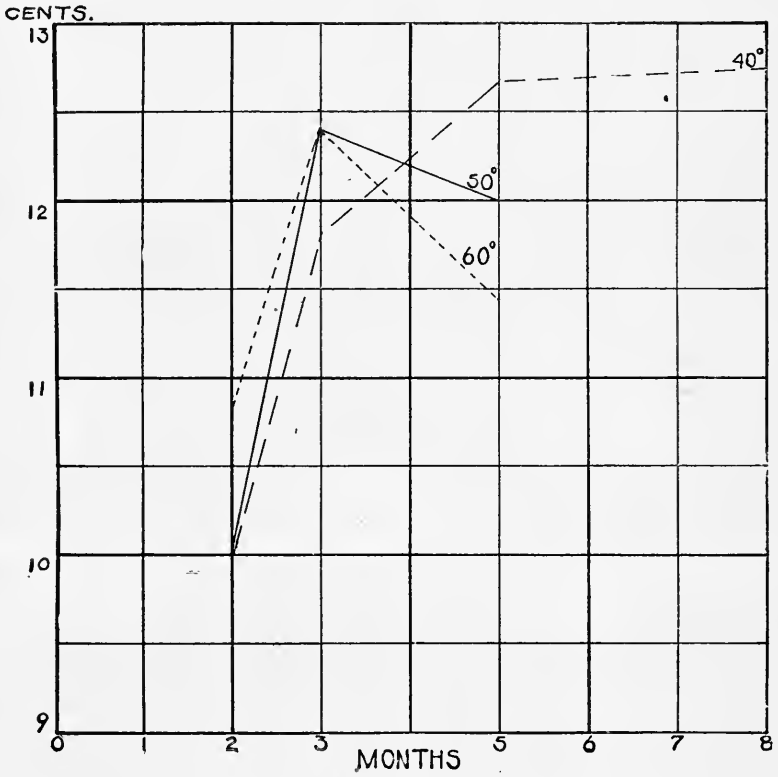


FIG. 16.—Price for type I.

The 50° cheese stands intermediate between the distinctively cold-cured product and that obtained under best present conditions without artificial refrigeration. Emphasis has already been laid upon the fact that a considerable improvement in quality is to be expected where a slight diminution in temperature is secured over that found in the best type of factory curing now in vogue. This system of "cool-curing"—that is, the use of a temperature from 52° to 58° F., as recently advocated by the Canadian authorities[a]—stands midway between the cold-curing process and the system now most frequently in use. The benefits to be gained by this system are evident from the Canadian experiments, in which 480 pairs of cheeses were cured, one

[a] J. A. Ruddick in paper presented at the Ontario Dairymen's Association, January, 1903.

of each lot being kept at 52° to 58°, while the other was ripened in an ordinary curing room (61° to 70°). Quoting Mr. Ruddick's paper, he

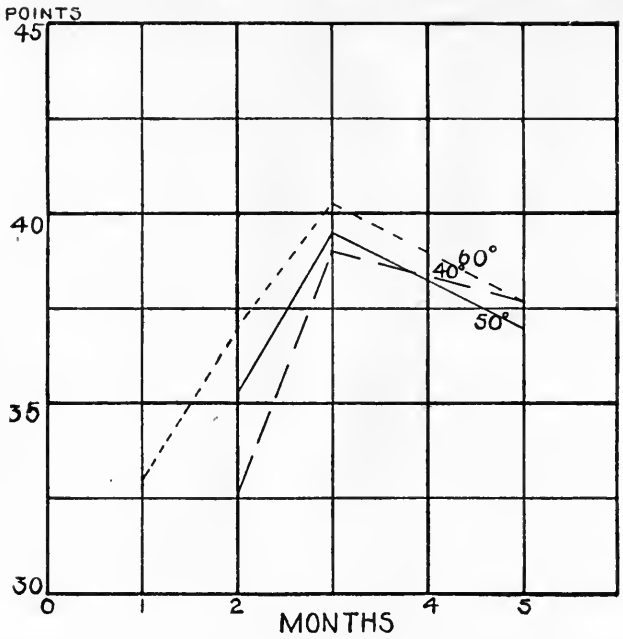


FIG. 17.—Flavor for type II.

says that "in every case the cool cured (cheese) nas been pronounced the best in quality."

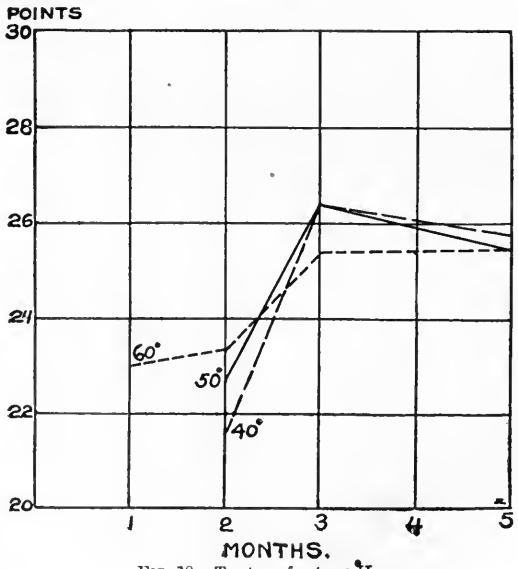


FIG. 18.—Texture for type II.

From the experiments detailed above it appears that further improvement in quality is possible if the curing temperature is still

further reduced (40° to 50° F.). It must be remembered in this comparison that the highest temperature we employed is much lower than the average factory curing room. The difference in quality between cold-cured and ordinary-cured cheese would be much greater than that represented in this work.

The cheese of this type at 60° ripened rapidly and showed an excellent quality in all lots but one, which was tainted from the beginning, but they all passed their prime in three months and showed marked deterioration by the end of five months.

With this type of cheese it must be remembered that the quality of the flavor produced at low temperatures is quite different from that found at 60°. Cold-cured cheese possesses a very mild but perfectly clean flavor, together with a solid waxy texture.

Course of Ripening in Type II.

The cheese in this type is not so uniform in its make-up as that of type I, but it represents that type of American product in which less acid is developed than is found in the normal Cheddar cheese. This cheese is more open in texture and contains a considerable number of mechanical and small Swiss holes as shown in Plate III. The cheese was somewhat low in flavor, due in all probability to the milk and method of manufacture, and not to the curing, as this defect was quite as apparent at the lower temperatures as at 60°.

The Iowa cheese was found to be of only fair quality, but at all ages was better at 40° than at other temperatures, although the difference is considerably less than it was with the firmer Wisconsin type of cheese.

The Illinois cheese was quite similar to the Iowa lot, but the texture of this cheese at 60° was considerably more impaired than that obtained at the lower temperatures.

The following table gives the summary of the scores of these two lots (Iowa and Illinois) taken at intervals during the life of the cheese.

Summary of scores of cheese and values in type II (sweet-curd).

Age in months.	Flavor (standard 45).			Texture (standard 30).			Price (standard 13 cents).		
	40°.	50°.	60°.	40°.	50°.	60°.	40°.	50°.	60°.
1	.....	.....	35	.....	.....	22	.....	.....	9.5
2	37.5	38	36.5	23.5	25	22	10	10.25	9.75
3	40.5	40.5	40	27	26	23.5	11.7	11.13	10.87
5	39	38	35	26	26	25	11	10.75	10.25

In the accompanying diagrams the above tabular data are pictorially represented.

Flavor.—Figure 17 shows the course of development of the flavor. While there was not much difference in the maximum flavor produced (one-half point), still the cold-cured cheese maintained a higher flavor than the 60° throughout the whole experiment. The rapid deterioration of the 60° was especially marked.

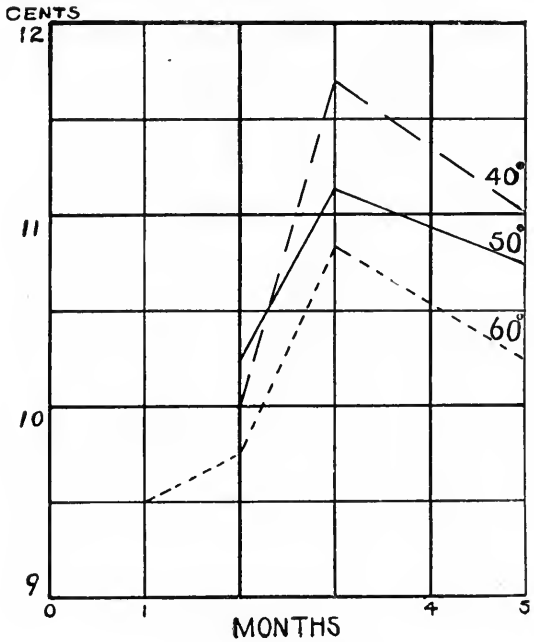


FIG. 19.—Price for type II.

Texture.—In texture, both the 40° and 50° were much superior to the 60° cheese, as is evident from figure 18.

Attention should also be directed in Plate III to the presence of the numerous white specks which only appear in the cold-cured cheese.

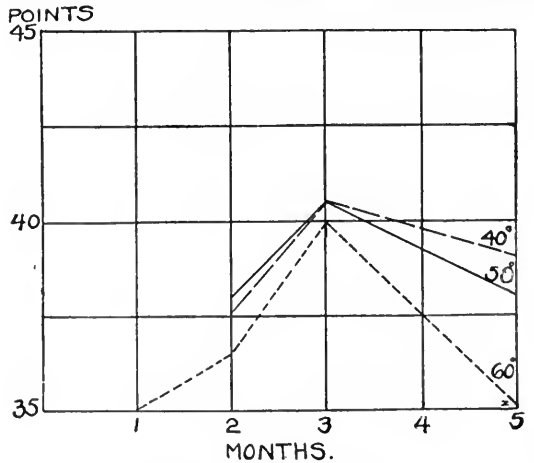
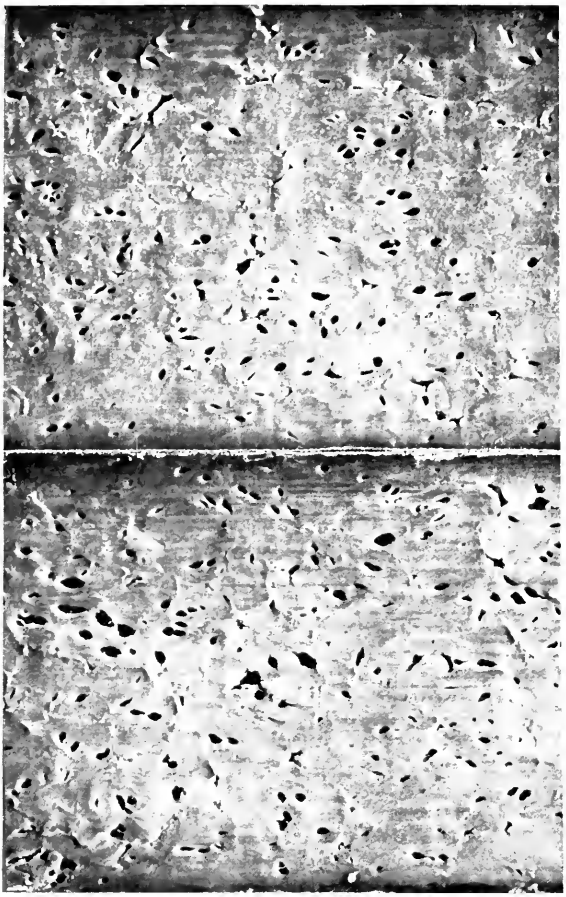


FIG. 20.—Flavor for type III.



Two Cheese Sections—Type II.

Cheese cured at 40° on top, cheese cured at 60° on bottom.

These small spots have always been found in our cheese cured at temperatures of 50° and below.

Price.—The commercial standard shows again the improvement in value and the maintenance of this improved condition for a longer period of time, as is evident from figure 19.

COURSE OF RIPENING IN TYPE III.

This type represents the softer make of cheese intended for home trade, and one which cures more quickly, and therefore does not keep

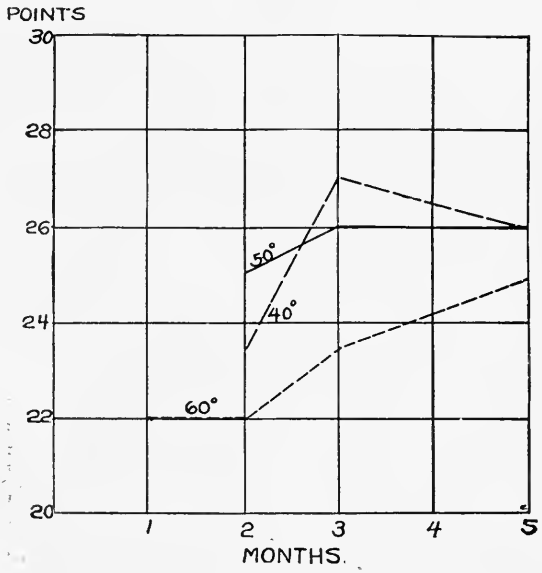


FIG. 21.—Texture for type III.

as long as the firmer Cheddar type. This type is represented by four different lots of Michigan cheese made at the same factory. They were not of standard quality, but were too acid. The first three lots were materially delayed in transit and consequently had undergone considerable change before being cold-cured. From the detailed data given in the appendix (p. 68–70) it is evident that lot 4 was the best, and in this lot the 40° and 50° were both better than the 60°.

The average results at the different temperatures are shown in the following table:

Summary of scores and values of cheese in type III (soft Michigan cheese).

Age (months).	Flavor (standard 45).			Texture (standard 30).			Price (standard 13 cents).		
	40°	50°	60°	40°	50°	60°	40°	50°	60°
1	.....	.....	33	.....	.....	23	.....	.....	9
2	32.6	35.3	37	21.7	22.7	23.3	9.3	10.2	10.5
3	39	39.5	40.2	26.3	26.3	25.3	11.25	11.4	11.5
5	37.7	37	37.7	25.8	25.5	25.5	10.4	10.2	10

Flavor.—In this case the flavor of the 4 lots was poor, only once exceeding 40 points. While the 60° scored higher at one time than the cheese at the other two temperatures, the 40° cheese at five months equaled the flavor of the higher temperature cheese at this time, as is shown in the table and also in figure 20.

Texture.—Figure 21 shows graphically the texture scores presented in the above table. The 60° cheese was materially better in the beginning, but fell slightly behind at the three months' period.

Price.—The difference in price of this cheese at three months was inconsequential, and from this date the cheese at all temperatures fell off rapidly in value as shown in figure 22.

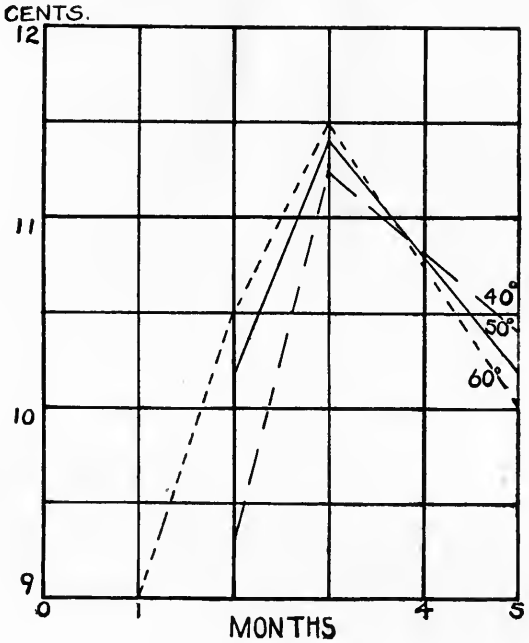


FIG. 22.—Price for type III.

All four lots of these Michigan goods were more or less delayed in transit, although lot four was no more so than some of the cheese in the other types. But with this moist, quick-curing cheese it was much more susceptible to temperature influences, and hence was materially impaired before being put in storage. This condition, taken in connection with the inferior make (high acid), renders this part of the experiment unsatisfactory.

B. EXAMINATION BY COMMERCIAL EXPERTS.

In accordance with the plan originally outlined, the cheese in these experiments was subjected to a close examination by a jury of commercial experts, who had no knowledge as to the previous treatment

which the cheese had received. The complete data as to their scores, price assigned, etc., are given in the appendix (p. 57). From these data the following table of averages for each lot of cheese is compiled, including the scores made when the cheese was, respectively, three and five months old:

Comparison of average numerical and commercial scores made by jury when the cheese was 3 and 5 months old.

FIRST JURY TEST (3 MONTHS).

	At 40°.				At 50°.				At 60°.			
	Flavor.	Text.	Color.	Price.	Flavor.	Text.	Color.	Price.	Flavor.	Text.	Color.	Price.
Type I (typical Cheddar).												
Wisconsin:												
T. J., Boaz	41.3	25.8	11.8	12.3	43.3	27.6	14.3	12.6	42.3	28.6	14.0	12.4
H. J. N., Muscoda	42.3	26.3	15	12.2	44.1	27.8	15	12.6	43.6	27.8	15	12.5
P. H. K., Nicholson	44	28.6	14.8	12.8	44	28.3	14.6	12.6	43	26.3	14.2	12.3
La X, La Crosse	43.3	28.6	14.3	12.6	43	28.3	14.3	12.6	42	27.3	14.3	12.3
Total	170.9	109.3	55.9	49.9	174.4	112	58.2	50.4	171.9	110	57.5	49.5
Average	42.7	27.3	14	12.5	43.6	28	14.5	12.6	43	27.5	14.4	12.4
Type II (sweet-curd).												
Iowa:												
E. G. H., Union	42.6	27.6	13.6	12.3	42.6	26.6	13	12.2	42.6	28	13.2	12.4
Illinois:												
J. B. G., Sterling	40.6	25.6	14.3	11.2	40	25	14	11.1	40	24.6	14	11.1
Total	83.2	53.2	27.9	23.5	82.6	51.6	27	23.3	82.6	52.6	27.2	23.5
Average	41.6	26.6	13.9	11.7	41.3	25.8	13.5	11.6	41.3	26.3	13.6	11.7
Type III (soft).												
Michigan:												
A. H. B., Merrill, I	39.6	26.0	13	11.9	40.6	26.6	13	12.2	41	26	13	12.2
A. H. B., Merrill, II	40.6	26.3	12.5	11.8	41.6	27.6	13.3	12.1	40	26.6	12.6	12
A. H. B., Merrill, III	40.3	27.3	13	11.3	42.6	28	13.3	12	40.3	26.3	13	11.5
A. H. B., Merrill, IV	42	28	13.6	12.3	41	26.6	12.6	11.8	42	27	12.6	12
Total	162.5	107.6	52.1	47.3	165.8	108.8	52.2	48.1	163.3	105.9	51.2	17.7
Average	40.6	26.9	13	11.8	41.4	27.2	13	12	40.8	26.5	12.8	11.9

Comparison of average numerical and commercial scores made by jury when the cheese was 3 and 5 months old—Continued.

SECOND JURY TEST (5 MONTHS).

	At 40°.				At 50°.				At 60°.			
	Flavor.	Text.	Color.	Price.	Flavor.	Text.	Color.	Price.	Flavor.	Text.	Color.	Price.
Type I (typical Cheddar).												
Wisconsin:												
T. J., Boaz	43.5	28.5	15.0	12.8	40.0	28.5	15.0	12.5	38.5	28.5	15.0	12.4
H. J. N., Muscoda	44	29.5	15	13	43.5	28.5	15	12.9	43	28	15	12.8
P. H. K., Nicholson	41	28	15	12.6	41.5	28.5	15	12.6	42	28.5	15	12.8
La X, La Crosse	41	27.5	13.5	12.1	40	26.5	12.5	11.9	35	25	14	11
Total	169.5	113.5	58.5	50.5	165	112	57.5	49.9	158.5	110	59	49
Average	42.4	28.4	14.6	12.6	41.2	28	14.4	12.5	39.6	27.5	14.7	12.2
Type II (sweet-curd).												
Iowa:												
E. G. H., Union	41.5	26	13	12	39.5	25	13	11.5	.....	.....	.....	.....
Illinois:												
J. B. G., Sterling	38.5	24.5	13.5	11	39	25.5	13.5	11.1	39	25	13.5	11
Total	80	50.5	26.5	23	78.5	50.5	26.5	22.6	.....	.....	.....	.....
Average	40	25.2	13.2	11.5	39.2	25.2	13.2	11.3	39	25	13.5	11
Type III (soft).												
Michigan:												
A. H. B., Merrill, I	36	26	11	11.6	36.5	26.5	11.5	11.8	37	26.5	11	11.6
A. H. B., Merrill, II	40	26	11	11	38.5	25.5	11	11	37.5	25.5	11	11
A. H. B., Merrill, III	38	27	13	11.3	39.5	25.5	11	11.4	38.5	26	12.5	11.4
A. H. B., Merrill, IV	43	27	12	12.3	42.5	27.5	12.5	12.3	40.5	25	11	11.8
Total	157	106	47	46.2	157	105	46	46.5	153.5	103	45.5	45.8
Average	39.2	26.5	11.7	11.5	39.2	26.2	11.5	11.6	38.4	25.7	11.4	11.4

In the first test the jury consisted of Messrs. White, Millar, and Kirkpatrick. In the second test, made when the cheese was 5 months old, one of the judges (Kirkpatrick) was unfortunately unable to assist. It is therefore impossible to compare with each other the average scores secured in these two tests, as the judgment of the different members of the jury naturally is not uniform. In comparing, therefore, the course of ripening in the three and five months' tests, it will be necessary to correct the averages given by eliminating the score of the judge who was absent in the second test.

For purposes of study, however, the two tests can be considered independently and the influence of the different temperatures on the character of the cheese determined.

Results of First Jury Trial.

When the cheese had been cured for three months, the sample cheese which had been tested previously at monthly intervals by Mr. Baer, was shipped by refrigerator service to Chicago and submitted to the jury for examination. In the appendix (p. 62) are given the

Three Cheese Sections—Illinois Cheese.

Cheese at top cured at 40°, in middle at 50°, and at bottom at 60°.

detailed data collected at this time. The average of these scores for the different types of cheese and at different temperatures is presented in the table on page 45. Necessarily these data must be discussed on the basis of the different types and not considered together. When this is done the following conclusions appear to be warranted.

Type I (*firm, solid, export cheese*).—In the four lots of cheese which comprised this group the 50° product was higher in flavor twice, the 40° once, and once the 40° and 50° were alike. In no case, even at this age, when the 60° cheese was at its best (as shown by the serial examinations made by Mr. Baer), did this cheese reach as fine a flavor as at the lower temperatures.

In texture the 40° lot was ahead twice, once the 50° and 60° were alike, and once the 60° was the highest.

As to price, in no case did the 60° equal the value set upon the cheese cured at the lower temperatures, although the difference given by the judges was slight. It must be remembered that the price assigned by the commercial jury was influenced materially by the fact that there is considerable difference in quality, even among the best types of cheese, without a corresponding difference in price. In the majority of cases, when the cheese scored within one or two points of perfect, the price was cut from a quarter to a half cent below the market standard (13 cents), simply because the appearance of the cheese on the surface (mold, etc.) warranted this reduction from a purely commercial point of view. The judges were free to admit that intrinsically the cold-cured cheese was of much better quality than is usually obtained in the market. This cheese was box-cured and received no especial care throughout the experiment: consequently the exterior appearance of the same had been impaired. With proper control this condition could have been entirely obviated, as we have been able to show repeatedly where cheese was cold-cured under our direct supervision.

Type II (*sweet-curd cheese*).—In this type, in which less acid was developed, little or no difference was observed in the Iowa goods; but in the Illinois cheese the 40° product had a better flavor and texture than the cheese cured at 50° or 60°. Plate IV shows the appearance of the Illinois cheese cured at the three temperatures when 3 months old.

Type III (*soft, home-trade cheese*).—This type is represented by four different lots from the same factory. All of the lots were highly acid and were of somewhat inferior make. Then, too, the earlier lots were delayed in transit from the factory to the curing station, so that the results of the experiment should not be considered as necessarily typical of the cold-curing process. In this group of four tests the 50° goods were ahead twice on flavor, the 60° once, and once the 40° and 60° were alike. In texture the 50° was highest three times out of four.

GENERAL SUMMARY OF THE FIRST (THREE MONTHS) TEST.

The cheese was examined at this date by the commercial judges, as it was thought that the highest temperature cheese (60°) had reached its maximum condition. It was naturally expected that the 60° product at this time would rank higher in quality than the cold-cured goods. From the above data, it is evident that such a condition did not obtain, as is indicated in the following summary of scores:

Summary of average scores for types I, II, and III, at three months.

	At 40°.	At 50°.	At 60°.
Average scores of ten lots on flavor	41.66	42.28	41.78
Average scores of ten lots on texture	27.01	27.24	26.85
Number of times each lot has highest score on flavor	2	4	1
Number of times each lot tied on score on flavor	3	2	2
Number of times each lot had highest score on texture	3	3	3
Number of times each lot tied on score on texture	0	1	1

From this it appears that the 50° cheese was superior in flavor and texture, not only on the basis of the total scores, but also as to the number of times they ranked highest or equal to the cheese cured at either of the other temperatures. This test was made before the 40° goods were marketable, but even at this time this cheese compared favorably with the 60° product.

RESULTS OF SECOND JURY TRIAL.

The second commercial scoring was made at the end of five months, at which time it was thought that the cold-cured goods could best be judged from a market point of view. The results of this scoring follow:

Type I.—In the four lots tested of this firm-bodied cheese, the 40° was highest in flavor three times and the 60° once. Averaging the total scores shows that the 40° cheese scored 2.8 points higher than the 60°, and even the 50° was 1.6 points above the cheese held at what has been considered ideal curing conditions.

In texture the 40° was highest twice, while in the other cases the scores were equal. Numerically, the average texture of the 40° was nearly a point above the 60°. At this age the 60° goods began to show signs of deterioration, while the cold-cured goods kept much better.

Type II.—In this test one lot of the 60° goods (Iowa) was mislaid in transit, and hence was not tested, but in this case the 40° was 2 points above the 50° in flavor, and 1 point on texture. In the Illinois cheese but little difference was observed.

Type III.—In this softer cheese, twice the 40° scored highest in flavor, the 50° and 60° once each. On texture the 40° scored highest twice, the 50° once, and the 50° and 60° tied once.

GENERAL SUMMARY OF SECOND (FIVE MONTHS) TEST.

In this test the average score, as well as the number of times any lot has scored the highest, shows that the 40° cheese was superior to those at either of the other temperatures, while at this age the 60° cheese showed that it had passed its prime. The summary of these scores is indicated below:

Summary of average scores for types I, II, and III, at five months.

	At 40°.	At 50°.	At 60°.
Average scores of nine lots on flavor	40.65	40.05	39.0
Average scores of nine lots on texture	27.0	26.75	26.4
Number of times each lot had highest score on flavor	6	1	2
Number of times each lot tied on score on flavor	0	1	1
Number of times each lot had highest score on texture	5	2	0
Number of times each lot tied on score on texture	1	3	3

COMPARISON OF THE FIRST AND SECOND JURY TRIALS AS INDICATING THE KEEPING QUALITY OF THE CHEESE.

It is important to compare the scores of the commercial judges made at the first and second jury trials, as in this way it is possible to study the keeping quality of the cheese cured at different temperatures. Unfortunately one of the judges could not be present at the second test. Therefore the judgment of the other two has been used in comparing the data of the two tests. The average scores of flavor and texture of these judges, made at the first and second trials, are given below:

Comparison of average scores made by the same judges at the 3 and 5 months' tests.

Type.	At 40° F.			At 50° F.			At 60° F.		
	Three months.	Five months.	Difference.	Three months.	Five months.	Difference.	Three months.	Five months.	Difference.
Flavor (standard 45).									
I	42.4	42.4	0	43.2	41.2	2	42.5	39.6	2.
II	41.5	40	1.5	41.3	39.2	2.1	41	39	2
III	40.3	39.2	1.1	40.8	39.2	1.6	40.4	38.4	2
Texture (standard 30).									
I	27	28.4	[a]−1.4	27.8	28	−0.2	27.2	27.5	−0.3
II	26.5	25.2	1.3	25.8	25.2	0.6	26	25	1.0
III	26.1	26.5	−0.4	27	26.2	0.8	26	25.7	0.3
Price (standard, 13 cents).									
I	12.4	12.6	−0.2	12.6	12.5	0.1	12.4	12.2	0.2
II	11.7	11.5	−0.2	11.6	11.3	0.3	11.7	11	0.7
III	11.6	11.5	0.1	11.9	11.6	0.3	11.9	11.4	0.5

[a] Where quality improved with age instead of deteriorating, it is indicated in column of difference by the use of the minus sign.

The above table is instructive in showing the progress of the curing at three and five months periods.

Type I.—With reference to flavor, type I showed its better keeping qualities, inasmuch as it held its own at 40°, while at 50° the cheese had deteriorated 2 points and at 60° 2.9 points. The texture improved at all temperatures as the age increased, but was much more pronounced (over a point) at 40° than at 50° or 60°. This improvement in flavor and texture is also reflected in the enhancement in commercial value. The 40° gained 0.2 cent per pound in three to five months, while the 50° fell off 0.1 cent and the 60° 0.2 cent per pound. Thus in all ways the advantage of cold curing is evident on this firm, solid type of the Wisconsin cheese.

Type II.—In this type, in which less acid was developed than in the typical Cheddar type, the deterioration in flavor was less at 40° than at either 50° or 60°. In texture, however, all scored lower at five months, the data showing a wider difference at 40° than at the other two temperatures. In price, however, the cheese was considered to be worth 0.2 cent per pound more at 40°, while the 60° cheese had depreciated 0.7 cent.

Type III.—In the softer Michigan make, in which more rapid deterioration would be expected, the falling off in flavor was 2 points at 60° as against 1.1 points at 40°. In texture the 40° improved 0.4 point, while the other two depreciated 0.8 and 0.3 point, respectively. In price, all these goods were of less value at five months than at three, but they had depreciated 0.5 cent at 60° and only 0.1 cent at 40°.

Summarizing the above, there can be no question but that the keeping quality of all of these various types of American cheese is improved by curing them at these lower temperatures. This is more evident with the firm, solid Wisconsin type of Cheddar than with the softer, quick-curing goods; but even these can be held with less deterioration at these temperatures than is possible under present curing conditions.

SUMMARY OF EFFECT OF TEMPERATURE ON QUALITY.

As the three different types of cheese represented in these experiments varied so much in character, it will be fairer to state the conclusions with relation to each separately. The scores on these lots of cheese were made separately by our own cheese expert throughout the whole curing period, and also at stated intervals by the commercial judges.

Type I (*firm-bodied, typical Cheddar cheese*).—At 60° F. flavor developed more rapidly than at lower temperatures, but the maximum score at this temperature, as indicated by Baer, was equaled or exceeded by the maximum score at 50° or 40°. In the scoring made by the

commercial jury the 50° averaged 0.6 point higher than the 60°, when cheese was 3 months old. When 5 months old, the 40° was 2.8 points higher than the 60°, and the 50° 1.6 points higher.

In texture the course of development was quite the same, the judges scoring the 50° ahead at 3 months, but at 5 months the 40° averaged nearly a point higher than the 60°.

Type II (*sweet-curd type*).—In this low-acid cheese the course for ripening followed the same rule as in the above type, although this cheese was inferior in quality to the preceding type.

Type III (*soft home-trade type*).—The results on this quick-curing type of cheese were affected by the delay in transit, which permitted of a considerable degree of ripening before the cheese was put in the curing rooms. In this type of cheese the improvement was less marked, but when the enhanced keeping quality is considered, the cold-curing process was found to be advantageous even under these advanced conditions.

C. INFLUENCE OF PARAFFINING ON QUALITY OF CHEESE.

With the use of lower temperatures for curing, a higher degree of saturation of the atmosphere is always found, which greatly promotes the development of mold, and this growth injures the salability, though not the quality, of the cheese, and hence many attempts have been made to overcome the difficulty. The most efficient method yet proposed is to coat the surface of the cheese with an impervious layer, which, by excluding oxygen, prevents development of molds. For this purpose the cheeses are immersed in a bath of melted paraffin, which, upon cooling, adheres closely to the surface. While this effectually accomplishes the desired end, it is a question of importance whether the quality of the cheese so treated is affected prejudicially or not. It is possible to conceive that the retention of all volatile decomposition products within the cheese might injure the flavor of the product.

In these cheese-curing experiments it was thought advisable to institute a series of trials to determine what influence paraffining had on the quality, as shown by the flavor and texture scores. For this purpose the cheese which was used in the experiments on shrinkage (La Crosse lot) was scored by Mr. Baer, and was also submitted to the experts for scoring at the regular periods. These scores are to be found in the appendix (pp. 58 and 64), but, in order to permit of a more

ready comparison, a summary of the flavor and texture scores of the paraffined and the normal cheese is presented in the following table:

Comparative scores of paraffined and unparaffined cheese (daisies and 10-pound prints).

20-POUND DAISIES.

Curing temperature.	Age by months.	Flavor.				Texture.			
				Difference.				Difference.	
		Paraffined.	Unparaffined.	Paraffined.	Unparaffined.	Paraffined.	Unparaffined.	Paraffined.	Unparaffined.
40° F	1	.....	30	.....	.....	.....	23	.....	.....
	2	30	34	.....	4	22	26	.....	4
	3	43.5	40	3.5	.....	29.5	29	0.5	.....
	a3	43.3	43.3	0	0	28.6	28.6	0	0
	5	40	40	0	0	29	28	1	.....
	a5	41.5	41	0.5	.....	27	27.5	.....	0.5
50° F	1	.....	30	.....	.....	.....	24	.....	.....
	2	33	35	.....	2	23	27	.....	4
	3	41	40	1	.....	28	29	.....	1
	a3	43	43	0	0	28.6	28.3	0.3	.....
	5	39	38	1	.....	28	27	1	.....
	a5	40.5	40	0.5	.....	26.5	26.5	0	0
60° F	1	30	28	2	.....	22	26	.....	4
	2	33	30	3	.....	26	27	.....	1
	3	38	38	0	0	27	29	.....	2
	a3	41.3	42	.....	0.7	27.6	27.3	0.3	.....
	5	38	35	3	.....	28	25	3	.....
	a5	39.5	35	4.5	.....	28	25	3	.....

10-POUND PRINTS.

40° F	1	38	38	0	0	22	22	0	0
	2	38	38	0	0	25	25	0	0
	a3	43.3	43	0.3	.....	28.3	27.6	0.7	.....
50° F	1	38	38	0	0	24	24	0	0
	2	41	41	0	0	26	26	0	0
	a3	43.3	43.3	0	0	28.6	28	0.6	.....
60° F	1	40	40	0	0	25	25	0	0
	2	43	42	1	.....	28	27	1	.....
	3	45	44.5	0.5	.....	29.5	29.5	0	0
	a3	43.3	42.6	0.7	.....	28.6	28.6	0	0

a This indicates that the score made at this time was by the commercial experts. Scores of same date not bearing reference mark are by Mr. Baer.

From these data it is evident that the difference between the same lot of cheese when paraffined or unparaffined is very slight. If the course of curing is considered, as is shown by the scores of Mr. Baer, which were taken when the cheese was 1, 2, 3, and 5 months old, it is apparent that the application of paraffin has not injured either the flavor or the texture of the cheese. By reference to the column headed "Difference" in the above table, it will be further noted that in the daisies the unparaffined cheese was, with one exception (60°),

better at the beginning; but throughout the remainder of the curing and to the end of the experiment the paraffined improved much more rapidly, and without exception was as good as or better than the unparaffined.

With the prints the difference in scores was practically negligible.

This same cheese was scored by the commercial experts when it was three and five months old, and it should be noted that the opinions of these experts coincided quite closely with those of Mr. Baer.

It would be unsafe from these limited experiments to draw any general conclusions, but so far as they go these trials show that no injurious effect was observed on either the flavor or the texture of the paraffined cheese.

GENERAL SUMMARY.

The purpose of the experiments detailed above was to test the value of low temperatures for the curing of cheese made under widely different but commercial conditions. To accomplish this purpose, it was deemed advisable to purchase the product from a wide range of territory. This condition rendered it impossible to install the cheese in the curing rooms immediately after it was taken from the press, and hence the full effect of the process is not so evident as would have been the case if the cheese had not had any preliminary curing.

Naturally a comparison of the cold-curing process would be made with the conditions most frequently found in factories, but in these studies the low temperature cured product has been compared with cheese ripened at about 60° F.—a temperature which has hitherto been considered as the best for the ripening of Cheddar cheese.

EFFECT ON SHRINKAGE.

When cheese is cold-cured, the losses due to shrinkage in weight are greatly reduced over what occurs under ordinary factory conditions.

(1) *Influence of temperature.*—Cheese cured at 40° F. decreased in weight in ninety days from 1 to 1.4 per cent, while that cured at 50° and 60° F. lost fully three times as much. This saving would be still further increased if comparison were made between the results of cold curing and existing factory conditions. Under prevailing factory practice cheese is sold at a much earlier date than is advisable with cold-cured goods, but the loss under present conditions, for even as brief a curing period as twenty days, is fully four times as great as has occurred in these experiments in a ninety-day period (the minimum curing period recommended) under cold-curing conditions (40° F.). This saving in a factory making 500 pounds of cheese daily would average not less than 15 pounds of cheese per day for the entire season, or considerably more than this if only summer-made cheese was cold cured.

(2) *Influence of type of cheese.*—In these experiments different types of cheese were used, ranging from the firm, typical Cheddar to the soft, moist, quick-curing cheese made for the home trade. The losses with the firmer type were considerably reduced in comparison with the other, but the conditions to which the softer types of cheese were subjected were not as favorable (because of initial delays), and hence the losses with these types can not be relied upon with such definiteness. As this cheese was exceedingly moist, the total losses from the press were undoubtedly greater than here reported.

(3) *Influence of size of cheese.*—The size of package exerts a marked effect on the rate of loss. At ordinary temperatures, the smaller the cheese the more rapidly it dries out. This difference in loss diminishes as the temperature is lowered, and in our experiments at 40° F. was practically independent of the size. This condition, however, was undoubtedly attributable to the relative humidity of the curing room, which at 40° F. was 100 per cent.

(4) *Influence of paraffin.*—By coating the cheese with melted paraffin the losses at 60° were reduced more than one-half at 50°; the saving was somewhat less, and at 40° the losses observed on the paraffined cheese of both sizes used were slightly in excess of those noted on the uncoated cheese.

(5) As some loss occurs even in a saturated atmosphere, where evaporation is presumed not to take place, it implies that the shrinkage in weight of cheese under these conditions is not wholly due to desiccation, but is possibly affected by the production of volatile products that are formed by processes inherent in the curing of cheese.

EFFECT ON QUALITY.

(6) The three types of cheese above referred to can scarcely be compared closely with each other, as they were so different in their make-up and subjected to somewhat different conditions during transit. By far the most satisfactory portion of the experiment is that which relates to type I, in which the best quality of cheese was represented. With these firm, typical Cheddars the influence of temperature on curing could best be studied. This cheese was also placed in storage nearer the press than any of the other types, and hence the test as to the effect of the curing temperature was more satisfactory. In this type the 60° cheese was of excellent quality and naturally developed faster than the cold-cured goods, but in time it was surpassed by the cheese at the lower temperatures (50° and 40°), and, when the keeping quality of the latter was taken into consideration, it was found to be superior in every way to that cured at 60°. Even when the condition of the milk was not entirely perfect, the quality of the cold-cured cheese was better, although the original taint was not removed.

With the sweet-curd (type II) and the soft home-trade cheese (type

III) the effect of the disturbing influences previously noted rendered it impossible to obtain as satisfactory results, but, even under these adverse conditions, the 40° and 50° cheese generally ranked better than the 60°, and, when keeping quality was taken into consideration, was materially better.

This same cheese was also scored independently by commercial experts when three and five months old. The results obtained conform very closely to those mentioned above, and indicate the superiority of the cold-cured product (either at 50° or 40°) in comparison with the cheese cured at 60°. This improvement in quality reflects itself also in the commercial values which were placed upon the cheese cured at different temperatures, both by our own expert and also by the commercial judges.

In this low-temperature-cured cheese the flavor was remarkably mild but clean, and was free from all trace of bitterness or other taint. The texture was fine and silky and the body close.

(7) *Keeping quality.*—The keeping quality of the cold-cured cheese far excels that of the cheese ripened at higher temperatures. The better types of cheese cured at 40° F. are at present writing (eight months) still in their prime, while the 60° cheese has long since greatly deteriorated.

(8) *Effect of paraffin on quality.*—Portions of two lots of cheese were paraffined as they came from the press, but were otherwise handled the same as the unparaffined cheese. The results obtained showed that paraffining did not prejudicially affect their quality at any temperature. As paraffining greatly reduced the shrinkage, the beneficial effect of the system is obvious. The rapid introduction of the method in commercial practice further attests its value.

(9) The production of a thoroughly broken-down Cheddar cheese of mild, delicate flavor and perfect texture meets a demand which is impossible to satisfy with cheese cured at high temperatures. Without any question, if the general market can be supplied with this mild, well-ripened cheese, consumption will be greatly stimulated, not only by increasing the amount used by present consumers, but by largely extending the use of this valuable and nutritious article of food.

(10) The improvement in quality of cold-cured cheese, the enhanced keeping quality, and the material saving in shrinkage due to lessened evaporation are sufficient to warrant a considerable expenditure on the part of cheese producers in installing cold-curing stations.

The principle of increasing cost of equipment to lessen cost of production or augment gross earnings is recognized as a sound financial method by all large enterprises, and, while the expense involved is considerably more than is incurred under existing conditions, yet the advantages enumerated more than compensate for such expense where carried out under proper conditions.

(11) This system is particularly applicable where the product of a number of factories can be handled at one point, and such consolidated curing stations must be established before the cold-curing process can be economically introduced. Such stations are now successfully used in a number of localities. The greatest advantage will undoubtedly accrue from the use of this system of curing with summer-made cheese, but the process is equally applicable to cheese made at any season of the year.

APPENDIX.

In the following appendix are given the original data collected in the series of examinations made by Mr. Baer and the commercial experts. From these data are compiled the summaries which are presented in the text of the foregoing bulletin.

Results of examinations by Mr. Baer during progress of curing cheese in type I (firm, export Cheddar type).

LOT 1.—THOS. JOHNSTON, BOAZ, RICHLAND COUNTY, WIS.

NOTE.—The following observations were made by Mr. Baer upon receipt of the cheese at cold-curing station: Flavor, clean but low; body, close; texture, curdy but meaty; curd particles well cemented; color, straight, even; cheese, well made.

Curing temperature.	Age of cheese when examined.	Numerical scores.			Descriptive scores.			Commercial value (standard, 13 cents).
		Flavor (standard, 45).	Texture (standard, 30).	Color (standard, 15).	Flavor.	Texture and body.	Color.	
	Months.							
40° F.	1	35	24	15	Flat, low	Curdy	O. K	.....
	2	37	27	14	Flat	Curdy	Streaked	9
	3	40	29	14	Clean, low	Smooth	Wavy	10.5
	5	42	29	15	Clean	Stiff	O. K	12.5
	8	45	29	15	Clean, high.	Stiff, close	O. K	13
50° F.	1	38	22	15	Low	Stiff	O. K	.....
	2	40	24	15	Low	Stiff	O. K	10.5
	3	42	28	15	Low	Waxy	O. K	12.5
	5	38	29	15	Tainted	Loose	O. K	11.5
60° F.	1	38	24	15	Flat	Stiff	O. K	.....
	2	43	25	15	Flat	Stiff	O. K	11.5
	3	44	29.5	15	Clean	Silky	O. K	13
	5	36	27	15	Off	Loose	O. K	10.5

LOT 2.—H. J. NOYES, MUSCODA, GRANT COUNTY, WIS.

NOTE.—The following observations were made by Mr. Baer upon receipt of the cheese at cold-curing station: Flavor, clean; body, close, meaty; texture, smooth; color, bright, straight, natural amber; curd particles firmly cemented, not so dry and firm as lot 1.

	Months.							
40° F.	1	35	20	15	Flat, low	Curdy	O. K	.....
	2	37	21	15	Flat	Curdy	O. K	10
	3	41	26.5	15	Clean	Smooth	O. K	11.75
	5	45	30	15	Clean, high.	Silky	O. K	13.25
	8	45	30	15	Clean, high.	Silky	O. K	13.25
50° F.	1	35	21	15	Low	Curdy	Dull	.....
	2	35	22	15	Low	Curdy	Dull	10
	3	42	27	14	Clean	Mealy	Dull	12
	5	44	30	15	Clean, high.	Silky	O. K	13
60° F.	1	35	20	14	Low	Curdy	Dull	.....
	2	38	25	15	Low	Curdy	Dull	.....
	3	44	29.5	15	Clean, high.	Smooth	O K	13
	5	44	29	15	Clean, high.	Silky	O. K	13

Results of examinations by Mr. Baer during progress of curing cheese in type I (firm, export Cheddar type)—Continued.

LOT 3.—P. H. KASPER, NICHOLSON, WAUPACA COUNTY, WIS.

NOTE.—The following observations were made by Mr. Baer upon receipt of the cheese at cold-curing station: Flavor, high and clean; body, close and meaty; texture, smooth and silky; color, a splendid light amber, clear and straight; boxed and packed in excellent shape; cheese arrived in splendid condition; neatly bandaged and perfectly made; the finest cheese placed in storage.

Curing temperature.	Age of cheese when examined.	Numerical scores.			Descriptive scores.			Commercial value (standard, 13 cents).
		Flavor (standard, 45).	Texture (standard, 30).	Color (standard, 15).	Flavor.	Texture and body.	Color.	
	Months.							
40° F.	2	40	26	15	Clean	Smooth	O. K	12
	3	45	30	15	Clean	Silky	O. K	13
	5	45	30	15	Clean	Silky	O. K	13.25
	8	45	29	15	Clean, high.	Close, meaty.	O. K	13
50° F.	1	.....	.....	.....	Clean	Curdy	O. K	.....
	2	43	28	15	Clean	Smooth	O. K	12.5
	3	45	30	15	Clean	Silky	O. K	13
	5	44	30	15	Clean	Silky	O. K	13
60° F.	1	42	27	15	Clean	Smooth	O. K	12
	2	45	30	15	Clean	Smooth	O. K	13
	3	43	28	15	Clean	Loose	O. K	12
	5	43	29	14	Clean	Silky	O. K	12.75

LOT 4.—LA CROSSE CHEESE AND BUTTER CO., LA CROSSE, LA CROSSE COUNTY, WIS.

NOTE.—The following observations were made by Mr. Baer upon receipt of the cheese at cold-curing station: Flavor, not clean; body, close meaty; color, O. K.; cheese well made; the only fault found with this goods was the objectionable flavor, resembling that resulting from frozen feed.

20-pound daisies.

	Months.							
40° F.	1	30	23	12	Tainted	Curdy	O. K	.....
	2	34	26	12	Tainted	Waxy	O. K	9
	3	40	29	14	Tainted	Waxy	Wavy	12
	5	40	28	13	Low	Close	Wavy	11.75
	8	40	28	14	Off, flat	Fair	Wavy	11.75
50° F.	1	30	24	12	Tainted	Curdy	O. K	.....
	2	35	27	12	Tainted	Stiff	O. K	9
	3	40	29	14	Tainted	Waxy	O. K	12
	5	38	27	13	Tainted	Waxy	Mottled	10.5
60° F.	1	28	26	13	Tainted	Curdy	O. K	.....
	2	30	27	14	Tainted	Waxy	O. K	8
	3	38	29	14	Tainted	Smooth	O. K	11.5
	5	35	25	10	Tainted	Gassy	Faded	9.5

Results of examinations by Mr. Baer during progress of curing cheese in type I (firm, export Cheddar type)—Continued.

LOT 5.—LA CROSSE CHEESE AND BUTTER CO., LA CROSSE, WIS.

NOTE.—The following observations were made by Mr. Baer upon receipt of the cheese at cold-curing station: Flavor, clean but low; texture, good; color, O. K.; cheese well made and of fine quality.

10-pound prints.

Curing temperature.	Age of cheese when examined.	Numerical scores.			Descriptive scores.			Commercial value (standard, 13 cents).
		Flavor (standard, 45).	Texture (standard, 30).	Color (standard, 15).	Flavor.	Texture and body.	Color.	
	Months.							
40° F.	1	38	22	15	Clean	Curdy	O. K	
	2	38	25	15	Clean	Curdy	O. K	10
	3	43	27	15	Clean	Waxy	O. K	12
	8	42	27	15	Not clean	Mealy	O. K	12
50° F.	1	38	24	15	Clean	Curdy	O. K	
	2	41	26	15	Clean	Curdy	O. K	10.5
	3	43	27	15	Clean	Smooth	O. K	12.75
60° F.	1	40	25	15	Clean	Curdy	O. K	
	2	42	27	15	Clean	Smooth	O. K	12.75
	3	44.5	29.5	15	Clean, high.	Smooth	O. K	13

LOT 6.—LA CROSSE CHEESE AND BUTTER CO., LA CROSSE, WIS.

NOTE.—The following observations were made by Mr. Baer upon receipt of the cheese at cold-curing station: Flavor, not clean; body, close, meaty; color, O. K.; cheese well made, put up in neat, attractive form.

20-pound paraffined daisies.

	Months.							
	1				Low	Curdy	O. K	
	2	30	22	15	Low	Curdy	O. K	9
40° F.	3	43.5	29.5	15	Clean	Waxy	O. K	13
	5	40	29	14	Low	Waxy	O. K	12
	8	40	29	12	Off	Waxy, open	Mottled	11.75
	1				Low	Curdy	O. K	
50° F.	2	33	23	15	Low	Curdy	O. K	10
	3	41	28	15	Tainted	Smooth	O. K	12.25
	5	39	28	14	Low	Waxy	O. K	12
	1	30	22	15	Low	Curdy	O. K	9
60° F.	2	33	26	15	Tainted	Salvy	O. K	10.5
	3	38	27	15	Tainted	Salvy	O. K	11.5
	5	38	28	13	Tainted	Waxy	O. K	11.5

LOT 7.—LA CROSSE CHEESE AND BUTTER CO., LA CROSSE, WIS.

NOTE.—The following observations were made by Mr. Baer upon receipt of the cheese at cold-curing station: Flavor, clean but low; body, close, meaty; color, O. K.; cheese of very fine quality.

10-pound paraffined prints.

	Months.							
	1	38	22	15	Clean	Curdy	O. K	
40° F.	2	38	25	15	Clean	Curdy	O. K	10
	8	42	28	15	Not clean, high.	Mealy	O. K	12.25
50° F.	1	38	24	15	Clean	Mealy	O. K	
	2	41	26	15	Clean	Mealy	O. K	10.5
60° F.	1	40	25	15	Clean	Mealy	O. K	
	2	43	28	15	Clean	Stiff	O. K	12.75

Results of examinations by Mr. Baer during progress of curing cheese in type II (sweet-curd type).

LOT 1.—E. G. HODGES, UNION, IOWA.

NOTE.—The following observations were made by Mr. Baer upon receipt of the cheese at cold-curing station: Flavor, clean but low; sweet, insipid taste; body, slightly loose; texture crumbly; color, O. K.; very small Swiss holes.

Curing temperature.	Age of cheese when examined.	Numerical scores.			Descriptive scores.			Commercial value (standard 13 cents).
		Flavor (standard 45).	Texture (standard 30).	Color (standard 15).	Flavor.	Texture and body.	Color.	
	Months.							
40° F.	1	.....	.....	.....	Flat	Curdy	Wavy.....	.....
	2	40	24	14	Flat	Waxy	Wavy.....	10.5
	3	43	29	14	Low	Clean.....	Wavy.....	12.5
	5	41	27	14	Flat	Loose.....	Wavy.....	11.5
50° F.	1	.....	.....	.....	Flat	Curdy	Wavy.....	.....
	2	38	25	13	Flat	Waxy	Wavy.....	10.5
	3	43	27	13	Low	Open	Wavy.....	12.25
	5	40	27	14	Low	Loose.....	Wavy.....	11
60° F.	1	35	22	12	Low	Curdy	Wavy.....	9.5
	2	36	24	12	Flat	Waxy	Wavy.....	10
	3	40	27	12	Low	Open	Wavy.....	11.5

LOT 2.—J. B. GILBERT & CO., STERLING, ILL.

NOTE.—The following observations were made by Mr. Baer upon receipt of the cheese at cold-curing station: Flavor, clean but low; body, slightly loose; small Swiss holes; made soft and moist.

	Months.							
	1	.....	.....	.....	Low	Pasty.....	O. K	.....
40° F	2	35	23	15	Low	Pasty.....	O. K	9.5
	3	38	25	15	Low	Loose.....	O. K	10
	5	37	25	14	Flat	Pasty.....	O. K	10.5
	1	.....	.....	.....	Low	Pasty.....	O. K	.....
50° F	2	38	25	15	Low	Pasty.....	O. K	10
	3	38	25	15	Low	Pasty.....	O. K	10
	5	36	25	14	Low	Pasty.....	O. K	10.5
	1	35	22	15	Low	Pasty.....	O. K	9.5
60° F	2	37	22	15	Low	Pasty.....	O. K	9.5
	3	40	20	15	Low	Open	O. K	10
	5	35	25	14	Low	Pasty.....	O. K	10.25

Results of examinations by Mr. Baer during progress of curing cheese in type III (soft, home-trade type).

LOT 1.—A. H. BARBER & CO., MERRILL, MICH.

NOTE.—The following observations were made by Mr. Baer upon receipt of the cheese at cold-curing station: Flavor, fair; body, loose, open; slightly huffed; color, O. K.; slightly open under the bandage; too highly acid; packages poor.

Curing temperature.	Age of cheese when examined.	Numerical scores.			Descriptive scores.			Commercial value (standard 13 cents).
		Flavor (standard 45).	Texture (standard 30).	Color (standard 15).	Flavor.	Texture and body.	Color.	
	Months.							
40° F	1	.....	.....	.....	.....	Mealy, acid	O. K	.....
	2	30	21	14	.....	.....	.....	9.5
	3	35	24	14	Acidy	Sticky	O. K	11
	5	35	25	10	Sour	Mealy	Cut	9
50° F	1	.....	.....	.....	Acidy	Mealy	O. K	.....
	2	30	23	14	Acidy	Mealy	O. K	9.5
	3	35	26	14	Acidy	Pasty	O. K	11
	5	32	23	10	Sour	Mealy	Cut	8
60° F	1	31	22	12	Acidy	Mealy	O. K	8
	2	35	25	12	Acidy	Mealy	O. K	10
	3	38	22	14	Acidy	Pasty	O. K	11
	5	35	25	10	Sour	Mealy	Cut	9

LOT 2.—A. H. BARBER & CO., MERRILL, MICH.

NOTE.—The following observations were made by Mr. Baer upon receipt of the cheese at cold-curing station: Flavor, fair; body, loose, open; slightly huffed; color, O. K.; packages, poor, cheese started to mold.

	Months.							
40° F	3	40	27	12	Acidy	Pasty	Cut	11
	5	38	24	11	Acidy	Tallowy ...	Cut	11
50° F	3	41	28	12	Acidy	Salvy	Cut	11.5
	5	37	25	11	Acidy	Tallowy ...	Cut	10.5
60° F	3	41	28	12	Acidy	Salvy	Cut	11.5
	5	35	27	11	Acidy	Tallowy ...	Cut	10.5

LOT 3.—A. H. BARBER & CO., MERRILL, MICH.

NOTE.—The following observations were made by Mr. Baer upon receipt of the cheese at cold-curing station: Flavor, low but clean; body, slightly loose; texture curdy and short; cheese was soft; showed excess of moisture on the end surfaces; too highly acid; boxes badly broken and cheese moldy.

	Months.							
40° F	1	.....	.....	.....	Acidy	Mealy	O. K	.....
	2	33	22	14	Acidy	Mealy	O. K	9
	3	38	25	14	Acidy	Tallowy ...	Wavy	10
	5	38	27	12	Acidy	Loose	Cut	11
50° F	1	.....	.....	.....	Acidy	Mealy	O. K	.....
	2	38	23	14	Acidy	Mealy	O. K	10
	3	40	25	14	Low	Tallowy ...	O. K	11
	5	37	26	10	Acidy	Loose	Cut	10.5
60° F	1	.....	.....	.....	Not clean...	Mealy	O. K	.....
	2	38	23	14	Not clean...	Mealy	O. K	10
	3	40	28	14	Low	Salvy	O. K	11.5
	5	35	25	10	Acidy	Loose	Cut	10

Results of examinations by Mr. Baer during progress of curing cheese in type III (soft, home-trade type)—Continued.

LOT 4.—A. H. BARBER & CO., MERRILL, MICH.

NOTE.—The following observations were made by Mr. Baer upon receipt of the cheese at cold-curing station: Flavor, low but clean; body, loose; texture, short; cheese was soft; showed excess of moisture on rinds; boxes badly broken; cheese quite moldy.

Curing temperature.	Age of cheese when examined.	Numerical scores.			Descriptive scores.			Commercial value (standard 13 cents).
		Flavor (standard 45).	Texture (standard 15).	Color (standard 15).	Flavor.	Texture and body.	Color.	
	Months.							
40° F.	1	.....	.....	.....	Acidy	Short	Wavy	.....
	2	35	22	14	Acidy	Curdy	Wavy	9.5
	3	43	29	14	Low	Waxy	Wavy	12.75
	5	40	27	12	Low	Loose	Cut	10.75
50° F.	1	.....	.....	.....	Acidy	Short	Wavy	.....
	2	38	22	13	Acidy	Short	Wavy	11
	3	43	26	13	Flat	Short	Wavy	12
	5	42	28	12	Clean	Loose	Cut	11.75
60° F.	1	35	24	13	Acidy	Short	Wavy	10
	2	38	22	13	Acidy	Short	Wavy	11.5
	3	42	26	12	Flat	Short	Wavy	12
	5	38	25	12	Sour	Loose	Cut	10.5

SCORES BY INDIVIDUAL JUDGES AT THE COMMERCIAL TEST MADE AT FIRST AND SECOND JURY TRIALS.

Type I (firm export Cheddar type).

LOT 1.—THOS. JOHNSTON, BOAZ, RICHLAND COUNTY, WIS.

First jury trial (cheese 3 months old).

Curing temperature.	Judges.	Numerical scores.			Descriptive scores.			Price (standard, 13 cents).
		Flavor (standard 45).	Texture (standard 30).	Color (standard 15).	Flavor.	Texture.	Color.	
40° F.	White	43	28.5	13.5	Clean	Waxy ..	Specks ..	12
	Kirkpatrick	41	27	12	Low	Salvy ...	Mottled.	12.75
	Millar	40	22	10	Clean	Pasty ...	Mottled.	12.25
	Average	41.3	25.8	11.8	.....	.....	.....	12.33
50° F.	White	45	29	15	Perfect ..	Silky ...	O. K	12.5
	Kirkpatrick	44	28	14	Clean	Waxy ..	O. K	12.5
	Millar	41	26	14	Clean	Waxy ..	O. K	12.75
	Average	43.3	27.6	14.3	.....	.....	.....	12.58
60° F.	White	43	29	14	Clean	Smooth .	O. K	12.25
	Kirkpatrick	42	29	14	Tainted .	Silky ...	O. K	12
	Millar	42	28	14	Clean	Smooth .	O. K	13
	Average	42.3	28.6	14	.....	.....	.....	12.41

SCORES BY INDIVIDUAL JUDGES AT THE COMMERCIAL TEST MADE AT FIRST AND SECOND JURY TRIALS—Continued.

Type I (firm export Cheddar type)—Continued.

LOT 1.—THOS. JOHNSTON, BOAZ, RICHLAND COUNTY, WIS.

Second jury trial (cheese 5 months old).

Curing temperature.	Judges.	Numerical scores.			Descriptive scores.			Price (standard, 13 cents).
		Flavor (standard 45).	Texture (standard 30).	Color (standard 15).	Flavor.	Texture.	Color.	
40° F.	White	41	29	15	Clean	Waxy	O. K.	12.75
	Millar	43	28	15	Flat	Loose	O. K.	12.75
	Average	43.5	28.5	15				12.75
50° F.	White	40	29	15	Bitter	Smooth.	O. K.	12.5
	Millar	40	28	15	Bitter	Loose	O. K.	12.5
	Average	40	28.5	15				12.5
60° F.	White	39	29	15	Off	Smooth.	O. K.	12.5
	Millar	38	28	15	Off	Smooth.	O. K.	12.25
	Average	38.5	28.5	15				12.375

LOT 2.—P. H. KASPER, NICHOLSON, WAUPACA COUNTY, WIS.

First jury trial (cheese 3 months old).

40° F.	White	41	29	14.5	Clean	Waxy	O. K.	12.75
	Kirkpatrick	45	29	15	Clean	Silky	O. K.	12.75
	Millar	43	28	15	Clean	Waxy	O. K.	12.75
	Average	44	28.6	14.8				12.75
50° F.	White	41	29.5	14.5	Clean	Silky	O. K.	12.75
	Kirkpatrick	45	28.5	14.5	Clean	Waxy	O. K.	12.5
	Millar	43	27	15	Clean	Loose	O. K.	12.75
	Average	44	28.3	14.6				12.6
60° F.	White	44	27	14.5	Clean	Loose	O. K.	12.5
	Kirkpatrick	43	27	14	Flat	Pasty	O. K.	12
	Millar	42	25	14	Flat	Salvy	O. K.	12.25
	Average	43	26.3	14.16				12.25

LOT 2.—P. H. KASPER, NICHOLSON, WAUPACA COUNTY, WIS.

Second jury trial (cheese 5 months old).

40° F.	White	41	29	15	Clean	Smooth.	O. K.	13
	Millar	38	27	15	Flat	Loose	O. K.	12.12
	Average	41	28	15				12.56
50° F.	White	43	29	15	Bitter	Smooth.	O. K.	13
	Millar	40	28	15	Clean	Smooth.	O. K.	12.25
	Average	41.5	28.5	15				12.62
60° F.	White	42	29	15	Sharp	Smooth.	O. K.	13
	Millar	42	28	15	Clean	Smooth.	O. K.	12.5
	Average	42	28.5	15				12.75

SCORES BY INDIVIDUAL JUDGES AT THE COMMERCIAL TEST MADE AT FIRST AND SECOND JURY TRIALS—Continued.

Type I (firm export Cheddar type)—Continued.

LOT 3.—H. J. NOYES, MUSCODA, GRANT COUNTY, WIS.

First jury trial (cheese 3 months old).

Curing temperature.	Judges.	Numerical scores.			Descriptive scores.			Price (standard, 13 cents).
		Flavor (standard 45).	Texture (standard 30).	Color (standard 15).	Flavor.	Texture.	Color.	
40° F.	White	42	28	15	Flat	Pasty	O. K.	12
	Kirkpatrick	44	27	15	Clean	Salvy	O. K.	12.25
	Millar	41	24	15	Flat	Salvy	O. K.	12.25
	Average	42.3	26.3	15				12.16
50° F.	White	44.5	29	15	Perfect	Silky	O. K.	12.75
	Kirkpatrick	45	28.5	15	Clean	Waxy	O. K.	12.5
	Millar	43	26	15	Clean	Waxy	O. K.	12.5
	Average	44.1	27.8	15				12.58
60° F.	White	43	28.5	15	Clean	Silky	O. K.	12.5
	Kirkpatrick	45	29	15	Clean	Silky	O. K.	12.5
	Millar	43	26	15	Clean	Silky	O. K.	12.5
	Average	43.6	27.8	15				12.5

LOT 3.—H. J. NOYES, MUSCODA, GRANT COUNTY, WIS.

Second jury trial (cheese 5 months old).

40° F.	White	44	29	15	Clean	Smooth	O. K.	13
	Millar	44	30	15	Clean	Waxy	O. K.	13
	Average	44	29.5	15				13
50° F.	White	44	28	15	Clean	Smooth	O. K.	13
	Millar	43	29	15	Clean	Waxy	O. K.	12.75
	Average	43.5	28.5	15				12.87
60° F.	White	44	29	15	Clean	Waxy	O. K.	13
	Millar	42	27	15	Clean	Loose	O. K.	12.5
	Average	43	28	15				12.75

LOT 4.—LA CROSSE CHEESE AND BUTTER CO., LA CROSSE, LA CROSSE COUNTY, WIS.

First jury trial (cheese 3 months old).

40° F.	White	44	29	14	Clean	Waxy	O. K.	12.75
	Kirkpatrick	44	29	15	Clean	Salvy	O. K.	12.75
	Millar	42	28	14	Tainted	Waxy	O. K.	12.5
	Average	43.3	28.6	14.3				12.6
50° F.	White	44	29	14	Clean	Waxy	O. K.	12.75
	Kirkpatrick	44	29	15	Clean	Waxy	O. K.	12.75
	Millar	41	27	14	Tainted	Salvy	O. K.	12.5
	Average	43	28.3	14.3				12.6
60° F.	White	43	28	14	Flat	Smooth	O. K.	12.5
	Kirkpatrick	43	28	15	High	Silky	O. K.	12.25
	Millar	40	26	14	Tainted	Salvy	O. K.	12
	Average	42	27.3	14.3				12.25

SCORES BY INDIVIDUAL JUDGES AT THE COMMERCIAL TEST MADE AT FIRST AND SECOND JURY TRIALS—Continued.

Type I (firm export Cheddar type)—Continued.

LOT 4.—LA CROSSE CHEESE AND BUTTER CO., LA CROSSE, LA CROSSE COUNTY, WIS.

Daisies. Second jury trial (cheese 5 months old).

Curing temperature.	Judges.	Numerical scores.			Descriptive scores.			Price (standard, 13 cents).
		Flavor (standard 45).	Texture (standard 30).	Color (standard 15).	Flavor.	Texture.	Color.	
40° F.	White	40	28	13	Flat	Pasty	Wavy	12
	Millar	42	27	14	Flat	Loose	O. K	12.25
	Average	41	27.5	13.5				12.12
50° F.	White	40	28	12	Flat	Salvy	Wavy	11.75
	Millar	40	25	13	Tainted	Salvy	Faded	12
	Average	40	26.5	12.5				11.87
60° F.	White	35	25	13	Off	Loose	Faded	11
	Millar	35	25	13	Tainted	Salvy	Faded	11
	Average	35	25	13				11

LOT 5.—LA CROSSE CHEESE AND BUTTER CO., LA CROSSE, LA CROSSE COUNTY, WIS.

First jury trial (cheese 3½ months old).

40° F.	White	44	28	14	Clean	Waxy	O. K	12.5
	Kirkpatrick	43	28	15	Clean	Waxy	O. K	12.5
	Millar	42	27	13.5	Clean	Waxy	Wavy	12.25
	Average	43	27.6	14.1				12.41
50° F.	White	43	28	14	Flat	Waxy	O. K	12.5
	Kirkpatrick	44	28	15	Clean	Waxy	O. K	12.5
	Millar	43	28	14	Clean, low	Smooth.	O. K	12.5
	Average	43.3	28	14.3				12.5
60° F.	White	43	28	14	Flat	Smooth.	O. K	12.5
	Kirkpatrick	43	29	15	Clean	Waxy	O. K	12.5
	Millar	42	28	14	Clean	Smooth.	O. K	12.5
	Average	42.6	28.6	14.3				12.5

LOT 6.—LA CROSSE CHEESE AND BUTTER CO., LA CROSSE, LA CROSSE COUNTY, WIS.

First jury trial (cheese 3 months old).

40° F.	White	44	29	14	Clean	Waxy	O. K	12.75
	Kirkpatrick	44	29	15	Clean	Waxy	O. K	12.75
	Millar	42	28	14.5	Tainted	Waxy	O. K	12.5
	Average	43.3	28.6	14.53				12.6
50° F.	White	44	29	14	Clean	Smooth.	O. K	12.75
	Kirkpatrick	44	29	15	Clean	Waxy	O. K	12.75
	Millar	41	28	14.5	Tainted	Salvy	O. K	12.5
	Average	43	28.6	14.5				12.6
60° F.	White	43	28	14	Flat	Smooth.	O. K	12.5
	Kirkpatrick	41	28	15	Tainted	Pasty	O. K	12
	Millar	40	27	14	Tainted	Salvy	O. K	12.25
	Average	41.3	27.6	14.3				12.25

SCORES BY INDIVIDUAL JUDGES AT THE COMMERCIAL TEST MADE AT FIRST AND SECOND JURY TRIALS—Continued.

Type I (firm export Cheddar type)—Continued.

LOT 6.—LA CROSSE CHEESE AND BUTTER CO., LA CROSSE, LA CROSSE COUNTY, WIS.

Second jury trial (cheese 5 months old).

Curing temperature.	Judges.	Numerical scores.			Descriptive scores.			Price (standard, 13 cents).
		Flavor (standard 45).	Texture (standard 30).	Color (standard 15).	Flavor.	Texture.	Color.	
40° F.	White	43	26	14	Flat	Smooth.	O. K.	12.5
	Millar	40	28	13	Low	Salvy	Wavy	12
	Average	41.5	27	13.5				12.25
50° F.	White	42	26	12	Flat	Waxy	Specks	12
	Millar	39	27	13	Low	Salvy	Wavy	11.75
	Average	40.5	26.5	12.5				11.87
60° F.	White	41	25	10	Flat	Smooth.	Wavy	11.75
	Millar	38	26	13	Low	Loose	Wavy	11.5
	Average	39.5	25.5	11.5				11.62

LOT 7.—LA CROSSE CHEESE AND BUTTER CO., LA CROSSE, LA CROSSE COUNTY, WIS.

First jury trial (cheese 3 months old).

40° F.	White	44	29	14	Clean	Waxy	O. K.	12.75
	Kirkpatrick	43	28	15	Clean	Waxy	O. K.	12.5
	Millar	43	28	14	Clean	Smooth.	O. K.	12.75
	Average	43.3	28.3	14.3				12.6
50° F.	White	43	29	14	Flat	Smooth.	O. K.	12.75
	Kirkpatrick	41	28	15	Clean	Waxy	O. K.	12.75
	Millar	43	29	14	Clean	Waxy	O. K.	12.75
	Average	43.3	28.6	14.3				12.75
60° F.	White	44	29	14	Clean	Waxy	O. K.	12.75
	Kirkpatrick	43	29	15	Clean	Waxy	O. K.	12.5
	Millar	43	28	14	Clean	Smooth.	O. K.	12.75
	Average	43.3	28.6	14.3				12.6

SCORES BY INDIVIDUAL JUDGES AT THE COMMERCIAL TEST MADE AT FIRST AND SECOND JURY TRIALS—Continued.

Type II (sweet-curd type).

LOT 1.—E. G. HODGES, UNION, IOWA.

First jury trial (cheese 3 months old).

Curing temperature.	Judges.	Numerical scores.			Descriptive scores.			Price (standard, 13 cents).
		Flavor (standard 45).	Texture (standard 30).	Color (standard 15).	Flavor.	Texture.	Color.	
40° F	White	43	28	13	Flat	Stiff	Wavy	12.25
	Kirkpatrick	43	27	14	Clean	Waxy	O. K	12
	Millar	42	28	13	Clean	Waxy	O. K	12.5
	Average	42.6	27.6	13.6				12.25
50° F	White	43	26	13	Flat	Waxy	Wavy	12
	Kirkpatrick	43	27	13	Clean	Waxy	Wavy	12
	Millar	42	27	13	Clean	Waxy	Wavy	12.5
	Average	42.6	26.6	13				12.16
60° F	White	43	28	13	Flat	Stiff	Wavy	12.25
	Kirkpatrick	43	28	13.5	Clean	Waxy	Wavy	12.5
	Millar	42	28	13	Clean	Waxy	Wavy	12.5
	Average	42.6	28	13.16				12.4

LOT 1.—E. G. HODGES, UNION, IOWA.

Second jury trial (cheese 5 months old).

40° F	White	43	25	12	Low	Mealy	Wavy	12
	Millar	40	27	14	Low	Salvy	Dull	12
	Average	41.5	26	13				12
50° F	White	41	25	12	Off	Loose	Wavy	11.5
	Millar	38	25	14	Low	Weak	Dull	11.5
	Average	39.5	25	13				11.5

LOT 2.—J. B. GILBERT & CO., STERLING, ILL.

First jury trial (cheese 3 months old).

40° F	White	39	25	14	Low	Pasty	O. K	11
	Kirkpatrick	42	27	15	Low	Loose	O. K	11.5
	Millar	41	25	14	Low	Pasty	O. K	11
	Average	40.6	25.6	14.3				11.16
50° F	White	40	25	14	Low	Pasty	O. K	11
	Kirkpatrick	40	25	14	Low	Salvy	O. K	11.25
	Millar	40	25	14	Low	Pasty	O. K	11
	Average	40	25	14				11.08
60° F	White	40	25	14	Flat	Pasty	O. K	11
	Kirkpatrick	41	26	14	Low	Pasty	O. K	11.25
	Millar	39	23	14	Low	Pasty	O. K	11
	Average	40	24.6	14				11.08

SCORES BY INDIVIDUAL JUDGES AT THE COMMERCIAL TEST MADE AT FIRST AND SECOND JURY TRIALS—Continued.

Type II (sweet-curd type)—Continued.

LOT 2.—J. B. GILBERT & CO., STERLING, ILL.

Second jury trial (cheese 5 months old).

Curing temperature.	Judges.	Numerical scores.			Descriptive scores.			Price (standard, 13 cents).
		Flavor (standard 45).	Texture (standard 30).	Color (standard 15).	Flavor.	Texture.	Color.	
40° F	White	39	24	13	Low	Salvy	Wavy	11
	Millar	38	25	14	Low	Salvy	O. K	11
	Average	38.5	24.5	13.5				11
50° F	White	39	25	13	Low	Pasty	Wavy	11.25
	Millar	39	26	14	Low	Loose	O. K	11
	Average	39	25.5	13.5				11.12
60° F	White	38	24	13	Bitter	Salvy	Wavy	11
	Millar	40	26	14	Low	Loose	O. K	11
	Average	39	25	13.5				11

Type III (soft home-trade type).

LOT 1.—A. H. BARBER & CO., MERRILL, MICH.

First jury trial (cheese 3 months old).

Curing temperature.	Judges.	Numerical scores.			Descriptive scores.			Price (standard 13 cents).
		Flavor (standard 40).	Texture (standard 30).	Color (standard 15).	Flavor.	Texture.	Color.	
40° F	White	38	25	13	Tainted	Salvy	O. K	11.75
	Kirkpatrick	41	28	13	Acidy	Pasty	O. K	12
	Millar	46	25	13	Tainted	Salvy	O. K	12
	Average	39.6	26	13				11.9
50° F	White	38	25	13	Tainted	Salvy	O. K	11.75
	Kirkpatrick	43	29	13	Acidy	Pasty	O. K	12.5
	Millar	41	26	13	Tainted	Salvy	O. K	12.25
	Average	40.6	26.6	13				12.16
60° F	White	40	26	13	Tainted	Salvy	O. K	12
	Kirkpatrick	42	27	13	Acidy	Waxy	O. K	12.25
	Millar	41	25	13	Low	Pasty	O. K	12.25
	Average	41	26	13				12.16

LOT 1.—A. H. BARBER & CO., MERRILL, MICH.

Second jury trial (cheese 5 months old).

40° F	White	40	25	10	Off	Mealy	Cut	11.5
	Millar	32	27	12	Acidy	Pasty	Cut	11.75
	Average	36	26	11				11.62
50° F	White	40	25	10	Tainted	Tallowy	Cut	11.5
	Millar	33	28	13	Acidy	Salvy	Cut	12
	Average	36.5	26.5	11.5				11.75
60° F	White	39	25	10	Off	Tallowy	Cut	11.25
	Millar	35	28	12	Acidy	Pasty	Cut	12
	Average	37	26.5	11				11.62

SCORES BY INDIVIDUAL JUDGES AT THE COMMERCIAL TEST MADE AT FIRST AND SECOND JURY TRIALS—Continued.

Type III (soft home-trade type)—Continued.

LOT 2.—A. H. BARBER & CO., MERRILL, MICH.

First jury trial (cheese 3 months old).

Curing temperature.	Judges.	Numerical scores.			Descriptive scores.			Price (standard 13 cents).
		Flavor (standard 45.)	Texture (standard 30).	Color (standard 15).	Flavor.	Texture.	Color.	
40° F.	White	40	26	12	Acidy	Salvy	Wavy	11.5
	Kirkpatrick	42	28	12	Flat	Pasty	Wavy	11.5
	Millar	40	25	13	Acidy	Pasty	Mottled	12.25
	Average	40.6	26.3	12.5				11.75
50° F.	White	40	27	13	Acidy	Pasty	O. K	11.75
	Kirkpatrick	43	29	13	Clean	Waxy	O. K	12
	Millar	42	27	14	Acidy	Waxy	O. K	12.5
	Average	41.6	27.6	13.3				12.08
60° F.	White	40	27	12	Acidy	Pasty	Wavy	11.75
	Kirkpatrick	40	28	13	Tainted	Salvy	O. K	11.25
	Millar	40	25	13	Acidy	Tallowy	O. K	12
	Average	40	26.6	12.6				12

LOT 2.—A. H. BARBER & CO., MERRILL, MICH.

Second jury trial (cheese 5 months old).

40° F	White	38	25	10	Acidy	Tallowy	Cut	11
	Millar	42	27	12	Acidy	Tallowy	Cut	11
	Average	40	26	11				11
50° F	White	37	25	10	Acidy	Tallowy	Cut	11
	Millar	40	26	12	Acidy	Tallowy	Cut	11
	Average	38.5	25.5	11				11
60° F	White	37	24	10	Acidy	Tallowy	Cut	11
	Millar	38	27	12	Acidy	Tallowy	Cut	11
	Average	37.5	25.5	11				11

LOT 3.—A. H. BARBER & CO., MERRILL, MICH.

First jury trial (cheese 3 months old).

40° F.	White	40	27	12	Acidy	Close	Wavy	11
	Kirkpatrick	41	28	13	Acidy	Tallowy	Cut	11.5
	Millar	40	27	14	Acidy	Tallowy	O. K	11.5
	Average	40.3	27.3	13				11.3
50° F.	White	42	28	13	Low	Smooth.	Wavy	12
	Kirkpatrick	43	28	13	Clean	Tallowy	O. K	12
	Millar	42	28	14	Acidy	Smooth.	O. K	12
	Average	42.6	28	13.3				12
60° F.	White	40	27	12	Bitter	Salvy		11.5
	Kirkpatrick	42	27	13	Clean	Loose	O. K	11.75
	Millar	39	25	14	Acidy	Pasty	O. K	11.25
	Average	40.3	26.3	13				11.5

SCORES BY INDIVIDUAL JUDGES AT THE COMMERCIAL TEST MADE AT FIRST AND SECOND JURY TRIALS—Continued.

Type III (soft home-trade type)—Continued.

LOT 3.—A. H. BARBER & CO., MERRILL, MICH.

Second jury trial (cheese 5 months old).

Curing temperature.	Judges.	Numerical scores.			Descriptive scores.			Price (standard 13 cents).
		Flavor (standard 45).	Texture (standard 30).	Color (standard 15).	Flavor.	Texture.	Color.	
40° F.	White	40	26	14	Tainted	Smooth	O. K	11.5
	Millar	36	28	12	Tainted	Loose	O. K	11
	Average	38	27	13				11.25
50° F.	White	39	25	10	Tainted	Smooth	Wavy	11.25
	Millar	40	26	12	Tainted	Loose	O. K	11.5
	Average	39.5	25.5	11				11.37
60° F.	White	39	25	13	Tainted	Smooth	Specks	11.5
	Millar	38	27	12	Tainted	Loose	O. K	11.25
	Average	38.5	26	12.5				11.37

LOT 4.—A. H. BARBER & CO., MERRILL, MICH.

First jury trial (cheese 3 months old).

40° F.	White	42	27	13	Flat	Stiff	Wavy	12
	Kirkpatrick	42	29	14	Clean	Waxy	O. K	12.5
	Millar	42	28	14	Low	Waxy	O. K	12.5
	Average	42	28	13.6				12.3
50° F.	White	40	25	13	Flat	Mealy	Wavy	11.25
	Kirkpatrick	42	29	13	Clean	Pasty	O. K	12
	Millar	41	26	12	Low	Pasty	Wavy	12
	Average	41	26.6	12.6				11.75
60° F.	White	41	26	12	Flat	Mealy	Cut	11.5
	Kirkpatrick	43	28	13	Clean	Mealy	Wavy	12.25
	Millar	42	27	13	Flat	Pasty	Wavy	12.25
	Average	42	27	12.6				12

LOT 4.—A. H. BARBER & CO., MERRILL, MICH.

Second jury trial (cheese 5 months old).

40° F.	White	43	26	10	Flat	Mealy	Cut	12.25
	Millar	43	28	14	Clean	Smooth	Cut	12.25
	Average	43	27	12				12.25
50° F.	White	43	27	11	Flat	Smooth	Cut	12.5
	Millar	42	28	14	Flat	Smooth	Cut	12
	Average	42.5	27.5	12.5				12.25
60° F.	White	41	25	9	Flat	Mealy	Wavy	11.75
	Millar	40	25	13	Acidy	Pasty	Cut	11.75
	Average	40.5	25	11				11.75

EASTERN EXPERIMENTS, 1902–03.

Conducted by L. L. Van Slyke, G. A. Smith, and E. B. Hart,
Of the New York Agricultural Experiment Station.

SUMMARY.

(1) *Object of experiment.*—The investigation was undertaken by the United States Department of Agriculture in cooperation with this station, its object being to study, on a commercial scale under commercial conditions, the influence of different temperatures upon the cheese during the curing process.

(2) *Plan of experiment.*—Cheese was secured which represented the product of the States of New York, Pennsylvania, and Ohio, and placed in cold storage at the temperatures of 40°, 50°, and 60° F. These were examined commercially by a committee of experts when first placed in cold storage, and later after being in cold storage ten, twenty, twenty-eight, and thirty-five weeks. Cheeses of different sizes were used, weighing 70, 65, 45, 35, and 12½ pounds. Also, in one case, cheeses were covered with a coating of paraffin. Chemical analyses were made at intervals.

(3) *Loss of weight.*—The loss of weight increased with increase of temperature, being on an average in twenty weeks 3.8 pounds per 100 pounds of cheese at 40° F., 4.8 pounds at 50° F., and 7.8 pounds at 60° F. The large-sized cheeses lost less weight per 100 pounds than those of smaller size.

(4) *Results of scoring cheese.*—Cheese cured at 40° F. was superior in quality to the same kind cured at higher temperatures. That cured at 50° F. was superior in quality to that cured at 60° F. The general averages of the scores at the end of twenty weeks were as follows: 95.7 at 40° F., 94.2 at 50° F., and 91.7 at 60° F. The difference in quality was confined in most cases to flavor and texture, the color and finish being little or not at all affected in cheese that was in good condition at the beginning.

(5) *Effects of covering cheese with paraffin.*—The commercial qualities of cheese were favorably influenced after six months in the case of that covered with paraffin, especially in flavor. The loss of moisture was greatly lessened, amounting only to a fraction of a pound for 100 pounds of cheese at 40° F. and 50° F., and being only about one-fifth the average loss found at 60° F. with cheese not so treated. The cheeses were also perfectly clean and free from mold, while all the cheeses not treated with paraffin were covered with mold.

(6) *Results of chemical analysis.*—The amount of certain water-soluble nitrogen compounds in cheese, such as caseoses, peptones, amides, and ammonia, is used as a means for measuring chemically the degree of ripeness in cheese. The amount of water-soluble nitrogen compounds increases with the age of cheese and with the temperature at which the cheese is cured.

(7) *Some practical applications.*—Curing cheese at low temperatures increases the amount of cheese to sell by preventing loss of moisture, and covering cheese with paraffin increases still more the yield of marketable cheese. This saving amounts to several dollars a ton. Also, the improved quality of cheese cured at low temperatures gives such cheese a higher market price.

REPORT OF RESULTS OF CURING CHEESE IN COLD STORAGE.

INTRODUCTION.

On the part of the New York Agricultural Experiment Station at Geneva, the work of selecting cheese, sampling, and supervision was performed by George A. Smith, dairy expert, and L. L. Van Slyke, chemist of the station; E. B. Hart assisted in the chemical work. The New York Mercantile Exchange was requested to designate competent persons to judge the cheese upon a commercial basis, and, the subject being referred to the cheese committee of the exchange, the following members were named as trade experts for this service: C. S. Martin, representing the oldest and largest cheese house in New York; F. B. Swift, representing one of the largest cheese-exporting firms in Montreal and New York, and D. W. Whitmore, head of a well-known firm. On the part of the Department of Agriculture, B. F. Van Valkenburgh, dairy inspector, gave immediate personal supervision.

The cheese was cured in New York City and examined and scored there, from time to time, without removal from cold storage.

The plan of the experiment was to secure cheese representing the States of New York, Pennsylvania, and Ohio, to place this in cold storage at different temperatures, to have commercial examinations made from time to time by a committee of chosen experts, to weigh the cheese at intervals, and to make chemical analyses of it. The object of this work was to study during the curing process the effect of different temperatures and the effect of covering cheese with paraffin upon (1) the commercial quality of the cheese, (2) the loss of weight, and (3) the chemical changes taking place.

DESCRIPTION OF SOURCES AND CHARACTER OF DIFFERENT LOTS OF CHEESE USED IN THE EXPERIMENT.

The arrangements for carrying on the experiment were not completed until the latter part of September, when it was somewhat difficult to secure large-sized cheeses, because most of the factories were

making only the small home-trade size. We were able, however, to get the makers in two cases to make the large-sized cheeses for this special work, but they were not of the best quality in every respect.

Lot I comprised 21 cheeses, averaging 64 pounds in weight, made by A. B. Hargrave at Heuvelton, St. Lawrence County, N. Y. These were made from the mixed milk of September 26, which contained 3.8 per cent of fat. The milk was ripened to 4½ spaces by the Marschall rennet test at a temperature of 86° F. Rennet extract was used at the rate of 2½ ounces for 1,000 pounds of milk. The milk began to thicken in fifteen minutes. The curd was heated to 98° F. in forty-five minutes. One hour and twenty minutes later the curd showed one-eighth of an inch of fine threads by the hot-iron test, when the whey was removed. The curd was then packed, drained, and kept for three hours, after which it was milled, salted at the rate of 2 pounds for 1,000 pounds of milk, cooled to 80° F., and put in press.

This lot of cheese was shipped to New York on September 30 and placed in cold storage on October 6.

Lot II comprised 40 boxes of cheese, made by J. E. Case at Turtlepoint, Pa., during the third week in September. They averaged 45 pounds in weight. It was found impossible to get a special lot of cheese made in Pennsylvania for this work, and so it was decided to take some already made. These cheeses were therefore older when put into cold storage, and did not get the full benefit of ripening at lower temperatures. In making the cheese, a starter of lactic ferment was used and the milk ripened to about 5 spaces by the Marschall test at a temperature of 86° F. Rennet extract was used at the rate of 2½ ounces for 1,000 pounds of milk, and the curd was cut in about forty-five minutes. The subsequent heating was carried to about 100° F. The whey was removed as soon as the curd strung on a hot iron. After milling, the curd was allowed to stand about half an hour before salting, with frequent stirring, and then cooled to 90° F. Salt was added at the rate of 2½ pounds for 1,000 pounds of milk used.

This lot of cheese was placed in cold storage on October 6.

Lot III consisted of 44 cheeses, averaging in weight about 34 pounds. They were made by J. H. Searl at Lowville, Lewis County, N. Y., from the mixed night and morning milk of September 26. Half were uncolored (A) and half were colored (B). The milk contained 4 per cent of fat and 12.6 per cent of solids. The milk was ripened to 3½ spaces by the Marschall test at 84° F. Rennet extract was used at the rate of 2½ ounces for 1,000 pounds of milk. The curd was cut in twenty-five minutes, and fifteen minutes later heat was applied, the temperature of 98° F. being reached in fifty minutes. Forty minutes later the whey was removed, as the curd showed one-eighth of an inch of string by the hot-iron test. After packing and draining in the usual way the curd was milled about four hours after the removal of whey. Salt was added at the rate of 2 pounds for 1,000 pounds of milk used, and the curd was cooled to 80° F. and then put in press.

This lot of cheese was shipped to New York October 1 and placed in cold storage October 7.

Lot IV consisted of two different sizes of cheeses, made by C. S. Alger at Martinsburg, Lewis County, N. Y. There were 20 colored cheeses (A), each weighing about 65 pounds, and 28 cheeses of so-called Stilton size or style (B), each weighing about 12½ pounds. (These are ordinarily known in market as "Young Americas.") The cheese was made from mixed milk of September 29, containing 4 per cent of fat and 12.6 per cent of solids. The conditions of manufacture were normal.

This lot of cheese was shipped on October 3 and placed in cold storage October 8.

Lot V comprised 34 cheeses, made by E. S. Rice at Triumph, Ohio, each averaging in weight about 36½ pounds. Rennet extract was added at the rate of 3 ounces for 1,000 pounds of milk at 86° F. The curd was cut in thirty minutes and then heated to 104° F. in about thirty minutes, the whey being drawn an hour and a half later. Salt was added at rate of 2¼ pounds for 1,000 pounds of milk used.

This lot was shipped October 7 and placed in cold storage October 13, 1902.

Lot VI consisted of 40 cheeses, each cheese weighing about 70 pounds. It was not at first intended to include a comparative trial between cheese in natural form and coated with paraffin (according to the increasing commercial practice), and no cheese was purchased by the Department of Agriculture for this purpose. But at the request of the New York Agricultural Experiment Station, and through the liberal cooperation of Messrs. Martin & Co., this was accomplished. Martin & Co. furnished this lot of cheese at their own expense and risk, but they were added to the five purchased lots, divided among the three curing rooms, as later recorded, and subjected to the same conditions and examinations as the rest. The cheese contained in this lot represented two different dates of manufacture one week apart—October 10 (A) and October 17 (B).

This lot of cheese was made by H. Petrie at Turin, Lewis County, N. Y. The milk, of good quality in every respect, was warmed to 86° F. and a carefully prepared sour-milk starter added. It was then ripened to about 4 spaces by the Marschall test. Rennet extract was added at the rate of 2½ ounces for 1,000 pounds of milk. In twenty-five to thirty minutes the curd was cut, the cutting being somewhat fine, after which careful stirring was begun and continued until the pieces of curd were well separated and beginning to shrink. Heat was then applied, the temperature of 98° F. being reached in about forty-five minutes. Stirring was continued until the curd strung on the hot iron one-eighth of an inch, when the whey was removed. The curd was then matted, cut into pieces about 3 by 6 by 6 inches, and turned at intervals of six or eight minutes until the curd was well drained and solid. The curd was then piled until it acquired a smooth, velvety feeling, after which it was milled, spread out, stirred, and cooled until fat

started from it when squeezed in the hand. It was then salted at the rate of 2 pounds for 1,000 pounds of milk used, and finally put in press. Light pressure was applied at first—just enough to make the curd hold together in the form of the mold. At the end of one hour the cheeses were removed from the hoops, the cloths and outside of the cheeses rinsed with warm water, replaced in press, and pressure applied for eighteen hours.

This lot was placed in cold storage October 24, half of the number being covered with paraffin (Ap and Bp) and half being in natural condition (An and Bn).

LENGTH OF EXPERIMENT.

In February the cheese stored at 60° F. was removed and sold. In April the cheese stored at 50° F. was placed on the market, and also most of the cheese kept at 40° F. Some of the cheese that had been held at 40° F. was retained and kept until June 1, when it was sold, except some that was kept and placed at a temperature of 32° F. for further work.

DISTRIBUTION OF CHEESES IN COLD STORAGE.

Arrangements were made with the Merchants' Refrigerating Company of New York City to provide special rooms and take care of these different lots of cheese. Rooms were provided in which the temperatures could be controlled and kept at 40° F., 50° F., and 60° F. Automatic records were arranged in each room, showing the condition of the temperature continuously. The regulation of temperatures was remarkably well done; the variations from the desired point, for the entire period of storage, did not exceed 2° for the 60° room or 1° for the other rooms. It was an exceptionally good piece of work in maintaining even temperatures for thirty or forty successive weeks.

The different lots of cheese were distributed in the different temperatures in the manner indicated by the following table:

Distribution of cheese at different temperatures.

Lot.	Number and weight of cheeses at 40° F.		Number and weight of cheeses at 50° F.		Number and weight of cheeses at 60° F.	
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Number.*	*Pounds.*
I	10	645	6	384	5	325
II	18	811	12	535	10	448
III White	11	378	6	207	5	170
III Colored	11	371	6	204	5	171
IV Large	9	585	6	387	5	329
IV Stiltons	16	197	8	99	4	50
V	19	696	8	290	7	256
VI An	5	358	3	211	2	143
VI Ap	5	356	3	212	2	142
VI Bn	5	352	.....	.....	.....	.....
VI Bp	5	358	3	208	2	138

LOSS OF WEIGHT.

The following table gives the weights of the cheese kept at the different temperatures and the percentages of loss at the several dates stated:

Weights of cheese and percentages of loss at different temperatures.

Lot and description.	Date of weighing.	Room at 40° F.		Room at 50° F.		Room at 60° F.	
		Weight.	Loss.	Weight.	Loss.	Weight.	Loss.
		Pounds.	*Per cent.*	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*
I (New York export Cheddars)	Oct. 6	645	.....	384	.....	325	.....
	Feb. 13	616	4.5	367	4.4	303	6.8
	Apr. 10	611	5.3	361	6.0	.....	.....
	June 1	600	7.0	.....	.....	.....	.....
II (Pennsylvania Cheddars)	Oct. 7	811	.....	535	.....	448	.....
	Feb. 13	789	2.7	515	3.7	425	1
	Apr. 10	783	3.5	511	4.5	.....	.....
	June 1	774	4.5	.....	.....	.....	.....
III A (white)	Oct. 7	378	.....	207	.....	170	.....
	Feb. 13	362	4.2	195	5.8	155	8.8
	Apr. 10	357	5.6	192	7.2	.....	.....
	June 1	.....	.....	.....	.....	.....	.....
III B (colored)	Oct. 7	371	.....	204	.....	171	.....
	Feb. 13	360	3.0	193	5.4	157	8.2
	Apr. 10	355	4.3	189	7.4	.....	.....
	June 1	348	6.2	.....	.....	.....	.....
IV A (large)	Oct. 8	585	.....	387	.....	329	.....
	Feb. 13	559	4.4	366	5.4	305	7.3
	Apr. 10	554	5.3	365	5.7	.....	.....
	June 1	545	6.8	.....	.....	.....	.....
IV B (Stiltons, or Young Americas)	Oct. 8	197	.....	99	.....	50	.....
	Feb. 13	188	4.6	91	8.1	44	12.0
	Apr. 10	184	6.6	88	11.1	.....	.....
	June 1	179	9.1	.....	.....	.....	.....
V (Ohio flats)	Oct. 13	696	.....	290	.....	356	.....
	Feb. 13	664	4.6	271	6.6	233	9.0
	Apr. 10	658	5.5	266	8.3	.....	.....
	June 1	646	7.2	.....	.....	.....	.....
VI An (Export Cheddars, without paraffin)	Oct. 24	358	.....	211	.....	143	.....
	Feb. 13	349	2.5	206	2.4	137	4.2
	Apr. 10	346.7	3.1	202.7	4.0	.....	.....
	June 1	342	4.5	.....	.....	.....	.....
VI Ap (Same, paraffined)	Oct. 24	356	.....	212	.....	142	.....
	Feb. 13	355	0.3	211	0.5	140	1.4
	Apr. 10	354	0.6	210	0.9	.....	.....
	June 1	352.8	0.9	.....	.....	.....	.....
VI Bn (New York Cheddars, without paraffin)	Oct. 24	352	.....	.....	.....	.....	.....
	Feb. 13	340	3.4	.....	.....	.....	.....
	Apr. 10	336.5	4.4	.....	.....	.....	.....
	June 1	333.2	5.3	.....	.....	.....	.....
VI Bp (Same, paraffined)	Oct. 24	358	.....	208	.....	138	.....
	Feb. 13	357	0.3	207	0.5	136	1.5
	Apr. 10	356.6	0.4	207	0.5	.....	.....
	June 1	355.4	0.7	.....	.....	.....	.....

Showing weight lost by cheese.

Lot.	Average weight of each cheese.	Age when placed in cold storage.	Age when weighed.	Amount lost for 100 pounds of cheese—		
				At 40° F.	At 50° F.	At 60° F.
	Pounds.	*Days.*	*Weeks.*	*Pounds.*	*Pounds.*	*Pounds.*
I	64	9	20	4.5	4.4	6.8
I	64	9	28	5.3	6.0	.....
I	64	9	35	7.0	.....	.....
II	45	18	20	2.7	3.7	5.1
II	45	18	28	3.5	4.5	.....
II	45	18	35	4.5	.....	.....
III A	34	9	20	4.2	5.8	8.8
III A	34	9	28	5.6	7.2	.....
III B	34	9	20	3.0	5.4	8.2
III B	34	9	28	4.3	7.4	.....
III B	34	9	35	6.2	.....	.....
IV A	65	8	20	4.4	5.4	7.3
IV A	65	8	28	5.3	5.7	.....
IV A	65	8	35	6.8	.....	.....
IV B	12.5	8	20	4.6	8.1	12.0
IV B	12.5	8	28	6.6	11.1	.....
IV B	12.5	8	35	9.1	.....	.....
V	36.5	.....	19	4.6	6.6	9.0
V	36.5	.....	27	5.5	8.3	.....
V	36.5	.....	34	7.2	.....	.....
VI An	70	7	17	2.5	2.4	4.2
VI An	70	7	25	3.1	4.0	.....
VI An	70	7	32	4.5	.....	.....
VI Ap	70	7	17	0.3	0.5	1.4
VI Ap	70	7	25	0.6	0.9	.....
VI Ap	70	7	32	0.9	.....	.....
VI Bn	70	14	17	3.4	.....	.....
VI Bn	70	14	25	4.4	.....	.....
VI Bn	70	14	32	5.3	.....	.....
VI Bp	70	14	17	0.3	0.5	1.5
VI Bp	70	14	25	0.4	0.5	.....
VI Bp	70	14	32	0.7	.....	.....

From the data contained in the above table, we are enabled to make the following statements:

(1) The cheese continued to lose water in nearly every case as long as weighings were made. This was true of all temperatures.

(2) The loss of weight was least at 40° F. and increased with increase of temperature. At the end of twenty weeks the cheese in temperature 40° F. had lost on an average 3.8 pounds per 100; that in 50° F., 4.8 pounds; and that in 60° F., 7.8 pounds. The loss at temperature 40° F. was 1 pound less than at 50° F., and 4 pounds less than at 60° F. In other words, the loss at 60° F., as compared with the loss at 50° F., was three times as great as was the loss at 50° F., compared with the loss at 40° F. The loss of weight was proportionally greater at higher temperatures.

(3) If we determine the average weekly loss from the data given in this table, we find that during the first twenty weeks the loss was at the average rate of 3 ounces a week at 40° F., 3.8 ounces at 50° F., and 6.2 ounces at 60° F. From the twentieth to the twenty-eighth week the average weekly loss was 2.2 ounces at 40° F. and 3.2 ounces at 50° F. The cheese kept at 40° F. appeared to lose more moisture per week from April 10 to June 1 than previously.

(4) The size of cheese influences the loss of moisture. Small cheeses, other conditions being the same, lose a larger proportion of moisture in curing than do large cheeses, owing to the greater amount of surface relative to weight in the smaller cheeses. This tendency is shown by the following tabulated statement:

Weight lost per 100 pounds of cheese in twenty weeks.

Average weight of cheese.	At 40° F.	At 50° F.	At 60° F.
Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
70	2.5	2.4	4.2
45	2.7	3.7	5.1
35	3.9	5.9	8.5
12¼	4.6	8.1	12.0

It will be noticed that the variation is much less at 40° than at the higher temperature.

(5) The method of covering cheese with paraffin greatly reduces the loss of moisture. In VI An and Bn the cheeses were in natural condition, while in VI Ap and Bp they were covered with paraffin, being dipped in melted paraffin when a few days old. The loss of moisture in cheese covered with paraffin was only 0.3 pound per 100 pounds of cheese in twenty weeks at 40° F., 0.5 pound at 50° F., and 1.4 pounds at 60° F. In the same kind of cheese not thus covered the loss of moisture was much greater at all temperatures. By covering cheese with paraffin a saving in loss of moisture can be effected amounting to 5 or 6 pounds per 100 pounds of cheese at 60° F., and at 50° or below the total loss of moisture can be reduced to less than 1 pound per 100 pounds of cheese. In addition, the use of paraffin prevents the growth of molds. In every case cheeses covered with paraffin were entirely clean, while the others were more or less heavily coated with molds.

RESULTS OF COMMERCIAL EXAMINATION OF CHEESE.

Arrangements were made to have the cheese examined at intervals by the commercial experts already named, who were to score the cheeses separately, the basis of a perfect cheese being 50 for flavor, 25 for texture, 15 for color, and 10 for finish. We give the average of the scores in the following table:

Results of scoring of cheese.

Lot.	Date of examination.	Temperature of curing room.	Flavor.	Texture.	Color.	Finish.	Total score.	Remarks.
		°F.						
I	Oct. 6, 1902	.....	48	24	15	10	97	
	Dec. 15, 1902	40	48	24	15	10	97	
	.....do.....	50	46.5	23	15	10	94.5	
	.....do.....	60	46	22	15	10	93	
	Feb. 13, 1903	40	46.7	23.3	15	10	95	
	.....do.....	50	44.3	23	14.7	10	92	
	.....do.....	60	42.7	22	14.3	10	89	
	Apr. 10, 1903	40	46.3	23	14.7	10	94	Flavor not perfectly clean.
	.....do.....	50	44.7	22.7	14.6	10	92	Flavor somewhat tainted.
	June 1, 1903	40	48	24.7	15	10	97.7	Clean flavor and silky texture.
II	Oct. 6, 1902	.....	48	24	15	10	97	
	Dec. 15, 1902	40	48	23.5	15	10	96.5	
	.....do.....	50	48	23	15	10	96	
	.....do.....	60	47	22.5	15	10	94.5	
	Feb. 13, 1903	40	46	22	15	10	93	
	.....do.....	50	45	22	15	10	92	
	.....do.....	60	44	22	15	10	91	
	Apr. 10, 1903	40	45.7	22.3	15	10	93	Flavor not perfectly clean.
	.....do.....	50	43.7	22.3	14.7	10	90.7	Flavor tainted.
	June 1, 1903	40	46	23	15	10	94	Flavor flat; texture smooth and silky.
III	Oct. 7, 1902	.....	48	24	15	10	97	
	Dec. 15, 1902	40	48.5	24	15	10	97.5	
	.....do.....	50	48	24	15	10	97	
	.....do.....	60	46.5	33	15	10	94.5	
	Feb. 13, 1903	40	47.7	23.7	15	10	96.4	Flavor clean; texture wax-like.
	.....do.....	50	47.7	24	15	10	96.7	
	.....do.....	60	45.3	23.3	14.8	10	94.4	
	Apr. 10, 1903	40	47.7	24	15	10	96.7	
	.....do.....	50	46.7	23.7	15	10	95.4	Flavor slightly bitter.
	June 1, 1903	40	47	24	15	10	96	Flavor clean; texture smooth and silky.
IV A	Oct. 8, 1902	.....	47	23	14	10	94	Rather acid and of imperfect color.
	Dec. 15, 1902	40	47.5	23.5	14	10	95	
	.....do.....	50	46.5	22.5	13.5	10	92.5	
	.....do.....	60	44.5	22	13.5	10	90	
	Feb. 13, 1903	40	44.7	22.7	13.3	10	90.7	
	.....do.....	50	42.3	22	12.3	10	86.6	
	.....do.....	60	41.7	21.3	12	10	85	
	Apr. 10, 1903	40	46	23	14.7	10	93.7	Flavor acid; texture stiff.
	.....do.....	50	43.3	22	13	10	88.3	Flavor acid and not clean; texture harsh; color imperfect.
	June 1, 1903	40	46	23	12.7	10	91.7	Flavor clean; texture smooth and silky; color light.

Results of scoring of cheese—Continued.

Lot.	Date of examination	Temperature of curing room.	Flavor.	Texture.	Color.	Finish.	Total score.	Remarks.
		°F.						
	Oct. 8, 1902	.....	48	23	15	10	96	
	Dec. 15, 1902	40	48	23.5	15	10	96.5	
	.....do.....	50	47.5	23.5	15	10	96	
	.....do.....	60	46.5	22.5	15	10	94	
	Feb. 13, 1903	40	47.3	23.7	15	10	96	
IV B.....	.....do.....	50	45	22	15	10	92	
	.....do.....	60	44	22	15	10	91	
	Apr. 10, 1903	40	46.3	24.3	15	10	95.6	
	.....do.....	50	46.3	24	14.7	10	95	
	June 1, 1903	40	46.7	23.3	15	10	95	Flavor clean; texture wax-like.
	Oct. 13, 1902	.....	46	23	15	10	94	
	Dec. 15, 1902	40	46.5	23.5	15	10	95	
	....do.....	50	45	22.5	15	10	92.5	
	....do.....	60	40.5	20.5	15	10	86	
	Feb. 13, 1903	40	45.3	21.3	14.7	10	91.7	
	....do.....	50	43.7	20.3	14.7	10	88.7	
V.....	....do.....	60	43	20	14.7	10	87.7	
	Apr. 10, 1903	40	45.3	22	14.7	10	92	Flavor and texture imperfect.
	....do.....	50	44	21.7	14.3	10	90	Slightly bitter and of weak texture.
	June 1, 1903	40	46	22.7	15	10	93.7	Flavor clean; texture smooth and pasty.
	Dec. 15, 1902	40	49	24	15	10	98	
	....do.....	50	48.5	23.5	15	10	97	
	....do.....	60	48	23.5	15	10	96.5	
	Feb. 13, 1903	40	48	24	15	10	97	
	....do.....	50	48	24	15	10	97	
VI. An...	....do.....	60	45.3	23	15	10	93.3	
	Apr. 10, 1903	40	48	24	15	10	97	
	....do.....	50	48	24	15	10	97	
	June 1, 1903	40	47.7	24.3	15	10	97	Surface covered with mold.
	Feb. 13, 1903	40	48	24	15	10	97	
	....do.....	50	48	24	15	10	97	
	....do.....	60	46.3	23.3	15	10	94.3	
	Apr. 10, 1903	40	48.3	24	15	10	97.3	
VI. Ap...	....do.....	50	48	24	15	10	97	
	June 1, 1903	40	48.7	24.3	15	10	98	Condition practically perfect; surface bright and clear.
	Feb. 13, 1903	40	48	24	15	10	97	
	....do.....	50	48	24	15	10	97	
	....do.....	60	44.7	22.7	14.3	10	91.7	
VI. Bu...	Apr. 10, 1903	40	48	24	15	10	97	
	....do.....	50	47	24	15	10	96	
	June 1, 1903	40	47.7	24.3	15	10	97	Surface covered with mold.
	Feb. 13, 1903	40	48	24	15	10	97	
	....do.....	50	48	24	15	10	97	
	....do.....	60	45.7	23	15	10	93.7	
	Apr. 10, 1903	40	48	24	15	10	97	
VI. Bp...	....do.....	50	47	24	15	10	96	
	June 1, 1903	40	48.7	24.3	15	10	98	Condition practically perfect; surface bright and clean.

SUMMARY.

From the data embodied in the preceding table, we are able to present the following statements as a summary of the results:

(1) Almost without exception the cheese cured at lower temperatures was superior in quality to that cured at higher temperatures. Cheese cured at 40° F. usually scored higher than that cured at 50° F., and the cheese cured at 50° F. scored higher in every instance than that cured at 60° F. Averaging all our results, we have the following general scores for the different temperatures: At 40° F., 95.7; at 50° F., 94.2; at 60° F., 91.7. From these figures we see that the cheese deteriorated considerably more at 60° F. as compared with 50° F. than it did at 50° F. as compared with 40° F. The difference of scores is 1.5 in favor of 40° F., as compared with 50° F., and 2.5 in favor of 50° F. as compared with 60° F. In other words, the higher the temperature the greater is the relative deterioration of cheese in quality for each degree of temperature.

(2) The difference in quality fell mostly on the flavor and texture. Averaging all the figures, we have the following results:

Averages of flavor and texture.

Qualities.	At 40° F.	At 50° F.	At 60° F.
Flavor	47.4	46.4	44.8
Texture	23.4	23	22.2

Here also we see that the difference is greater between 60° and 50° F. than between 50° and 40° F. in the direction of poorer quality.

(3) At any given time the cured at 40° F. was usually better in quality than that at 50°, and that at 50° was better than that at 60°. The longer the time of curing the greater was the difference in favor of the lower temperatures. The following tabulated averages of the results illustrate the statements:

Averages for different ages.

Age of cheese.	Score at 40° F.	Score at 50° F.	Score at 60° F.
Weeks.			
10	96.3	94.7	92
20	93.8	91.5	89.7
28	94.2	91.9	.....
35	95.3	.....	.....

The cheese cured at 60° showed such deterioration in quality at the end of twenty weeks that it was sold. While the cheese cured at 40° and 50° showed some deterioration in quality at twenty weeks, it scored higher at twenty-eight weeks than at twenty weeks. The cheese kept at 40° showed its highest score at thirty-five weeks in several cases.

The higher score was always in favor of the lower temperature by several points.

(4) The effect of covering cheese with paraffin was in several cases to improve the quality as compared with cheese not so covered. The difference was more marked at 60° than at lower temperatures. The cheese covered with paraffin and cured at 40° showed its highest score at the end of thirty-five weeks.

Results of use of paraffin.

Character of cheese.	Age in weeks.	At 40° F.	At 50° F.	At 60° F.
Cheese, normal (An)	20	97	97	93.3
Cheese, normal (Bn)	20	97	97	91.7
Cheese covered with paraffin (Ap)	20	97	97	94.3
Cheese covered with paraffin (Bp)	20	97	97	93.7
Cheese, normal (An)	28	97	97	.....
Cheese, normal (Bn)	28	97	96	.....
Cheese covered with paraffin (Ap)	28	97.3	97	.....
Cheese covered with paraffin (Bp)	28	97	96	.....
Cheese, normal (An and Bn)	35	97	.....	.....
Cheese covered with paraffin (Ap and Bp)	35	98	.....	.....

RESULTS OF CHEMICAL ANALYSIS OF CHEESE.

The analytical data upon which the following discussion of chemical results is based were obtained by the methods described in Bulletin No. 215 of the New York Agricultural Experiment Station, and the table giving these data in full may be found in Bulletin No. 234 of the same series. But in this work the paranuclein, caseoses, and peptones were not separated from one another, their combined amount being obtained by difference.

(1) *The process of cheese ripening.*—When cheese ripens, the most prominent change taking place is in the nitrogen compounds. The casein of milk is changed by the action of rennet enzyme into curd, chemically known as paracasein. In the process of cheese making, lactic acid is formed and this unites with the paracasein, forming a compound known as paracasein monolactate.[a] It is this compound that imparts to cheese curd the property of forming fine strings on a hot iron, and it is the formation of this paracasein monolactate that accounts for the changes in appearance, plasticity, and texture of cheese curd during the process of cheddaring. However, there is reason to believe that the changes that take place in the process of cheese-ripening start with and are dependent upon the presence of paracasein monolactate or some similar compound. Hence, from a chemical point of view, cheese ripening consists mainly of the change of paracasein monolactate into other forms of nitrogen compounds, chief among which in the order of their formation are paranuclein, caseoses, peptones, amido compounds, and ammonia. These com-

[a] Bull. No. 214, N. Y. Agricultural Experiment Station.

pounds, formed from paracasein monolactate, are readily soluble in water, while paracasein monolactate is not. Hence, in ripened cheese we have larger amounts of substances that are soluble and smaller amounts of substances that are insoluble. Ripened cheese is for this reason believed to be more readily digestible than green cheese. The amount of soluble nitrogen compounds is used as a measure of the extent of cheese ripening.

This present investigation offers an opportunity for studying the chemical results of cheese ripening under different conditions of temperature and with a number of different types of Cheddar cheese under commercial conditions.

(2) *Moisture in cheese.*—Before taking up a study of the nitrogen compounds of the cheese under investigation we will call attention to the amount of moisture in the cheese.

In the case of lots I, II, III, and IV, in which the moisture was determined when the cheese was placed in cold storage, the moisture content was found to vary from 34.20 to 35.44 per cent; this may be regarded as a comparatively small variation. In lots IV and V the moisture must have been above 40 per cent at the time the cheese was placed in cold storage, because ten weeks later, when the first analysis was made, the moisture was about 39 per cent. The result of moisture determination shows a gradual decrease in moisture as the cheese becomes older, as indicated by the following averages:

Per cent of moisture in cheese.

	At 40° F.	At 50° F.	At 60° F.
When put in cold storage	36.50	36.50	36.50
After being in storage ten weeks	36.30	35.70	35.65
After being in storage twenty weeks	35.35	34.66	34.26

The decrease of moisture is greater with increase of temperature, a point which has been dwelt upon in connection with loss of weight.

(3) *Amount of paracasein monolactate in cheese.*—The amount of paracasein monolactate formed in the different cheeses when one and two weeks old varied from 40.70 to 66.14 per cent of the nitrogen in the cheese and averaged 57.49 per cent. The amount decreased as the cheese aged, and more rapidly at higher than at lower temperatures, as shown by the following general averages:

Percentage of nitrogen in cheese in form of paracasein monolactate.

Age of cheese.	At 40° F.	At 50° F.	At 60° F.
1 week	57.49	57.49	57.49
10 weeks	47.94	42.08	37.09
20 weeks	47.10	35.24	30.77
28 weeks	40.54	31.82	.....
35 weeks	36.36	.....	.....

This diminution of paracasein monolactate is undoubtedly due to its conversion into water-soluble nitrogen compounds.

(4) *Amount of water-soluble nitrogen compounds in cheese.*—While the amount of water-soluble compounds of nitrogen in cheese is not a guide in respect to the detailed chemical changes taking place in ripening cheese, it serves as a general indication of the extent and rapidity of those changes. The data below, representing averages of our results, show that the amount of water-soluble nitrogen increases with increase of temperature and with lapse of time:

Percentage of nitrogen in cheese in form of water-soluble compounds.

Age of cheese.	At 40° F.	At 50° F.	At 60° F.
1 week	14.55	14.55	14.55
10 weeks	20.03	25.18	28.48
20 weeks	24.12	31.56	36.24
28 weeks	26.27	33.00	.....
35 weeks	27.64	.....	.....

(5) *Amount of amido compounds in cheese.*—The amido compounds of cheese are of interest because it is possible that among these compounds we are to look for the substance or substances responsible for cheese flavors. Little or no cheese flavor appears in cheese until amido compounds are formed. The amount of amido compounds increases with temperature and with lapse of time, as shown by the following averages:

Percentage of nitrogen in cheese in form of amido compounds.

Age of cheese.	At 40° F.	At 50° F.	At 60° F.
1 week	4.06	4.06	4.06
10 weeks	6.92	8.98	9.85
20 weeks	5.53	8.95	13.30
28 weeks	7.60	12.70	.....
35 weeks	9.00	.....	.....

(6) *Amount of ammonia in cheese.*—The formation of ammonia compounds in cheese may possibly be associated also with the development of cheese flavor. No ammonia is found in fresh cheese. It begins to be formed in appreciable quantities in about four weeks and increases with the age of the cheese. Its amount is greater at higher than at lower temperatures. The following averages give a good idea of the amount found in cheese under the conditions indicated:

Percentage of nitrogen in cheese in form of ammonia.

Age of cheese.	At 40° F.	At 50° F.	At 60° F.
1 week	0	0	0
10 weeks	1.20	1.87	1.97
20 weeks	1.62	3.44	3.36
28 weeks	2.52	3.48	.....

SOME PRACTICAL APPLICATIONS.

From the data presented in the foregoing pages, we have seen that the use of low temperatures in curing cheese shows two prominent results—(1) reduction of loss of weight and (2) improvement of commercial quality. Any reduction in loss of weight or any improvement in quality means an increase in the amount of money that can be realized in the sale of the cheese. It is a matter of practical interest and importance to consider in detail what specific increased or decreased market values were found for the cheese under the different conditions of experiment.

ECONOMY IN REDUCING LOSS OF MOISTURE.

We have seen that the loss of moisture in curing cheese can be reduced by using a lower temperature, or by covering cheese with a thin coating of paraffin, or by a combination of these two conditions.

Increased amount of cheese resulting from using low temperatures.—Taking the longest period of time for which we were able to compare the results at the different temperatures employed (twenty weeks), it was found that the cheese cured at 40° F. had lost, on an average, 3.8 pounds for 100 pounds of cheese; the cheese at 50° F. had lost 4.8 pounds, and that at 60° F. 7.8 pounds. For 100 pounds of cheese originally placed in the curing rooms at the different temperatures, we had for sale at the end of twenty weeks 96.2 pounds of cheese cured at 40° F., 95.2 pounds cured at 50° F., and 92.2 pounds cured at 60° F.

Assuming that the cheese sells at a uniform price of 10 cents a pound, there would be receipts from the original 100 pounds of each of the different cheeses as follows:

Cheese cured at 40° F	$9.62
Cheese cured at 50° F	9.52
Cheese cured at 60° F	9.22

Under these conditions, the receipts from the cheese kept at 40° F. are 10 cents per 100 pounds more than for that kept at 50° F. and 40 cents per 100 pounds more than that kept at 60° F. As will be pointed out later, the differences are really greater than this.

Increased amount of cheese resulting from covering cheese with a coating of paraffin.—At the end of seventeen weeks, cheese covered with

paraffin had lost only 0.3 pound for 100 pounds of cheese originally placed in storage at 40° F., 0.5 pound at 50° F., and 1.4 pounds at 60° F. The saving thus effected, based on the uniform price of cheese at 10 cents a pound, would average about 35 cents for 100 pounds of cheese cured at 40° F., 43 cents for 100 pounds at 50° F., and 64 cents for 100 pounds at 60° F.; or, comparing cheese kept at 40° F., covered with paraffin, with cheese kept at 60° F. not so covered, there would be a difference of about 75 cents per 100 pounds in favor of the paraffined cheese.

The cost of covering cheese with paraffin is slight. Conveniences for the work can be obtained from manufacturers of dairy supplies.

Increased value resulting from improvement in quality of cheese cured at low temperatures.—We have already studied the results of the scores furnished by the experts who examined the cheese from time to time. They were requested also to place upon the different lots of cheese a commercial valuation based upon the results of their scoring. Below we present these commercial valuations in tabulated form. The experts properly disregarded the actual market rates, which have fluctuations sometimes difficult to account for, and established as their constant basis of valuation 13 cents per pound for cheese scoring over 95 points.

Value of one pound of cheese.

Date of examination.	Temperature curing room.	Lot I.	Lot II.	Lot III.	Lot IV.		Lot V.	Lot VI.			
					A.	B.		An.	Ap.	Bn.	Bp.
	° F.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.
Dec. 15, 1902	40	13	13	13	13	13	13	13.75	13.75	13.75	13.75
Do	50	12.75	13	13	12.50	13	12.50	13.75	13.75	13.75	13.75
Do	60	12.50	12.75	12.75	12	12.75	11.75	13.75	13.75	13.75	13.75
Feb. 13, 1903	40	13	12.50	13	12	13	12.25	14.25	14.25	14.25	14.25
Do	50	12.25	12.25	13	11.75	12.25	12	14.25	14.25	14.25	14.25
Do	60	12	12.25	12.50	11.75	12.25	11.75	13.50	13.75	13.25	13.50
Apr. 9, 1903	40	12.75	12.50	13	12.50	13	12.50	14.75	14.75	14.75	14.75
Do	50	12.25	12.25	13	12	13	12.25	14.50	14.75	14.50	14.75
June 1, 1903	40	.....	.....	.....	.....	.....	.....	14.50	14.50	14.75	14.75

In studying the data embodied in this table, the following points are noticeable:

(1) In the case of lots I to V, the value of the cheese cured at 40° F. was greater in most cases than that cured at 50° F., and in every case greater than that cured at 60° F. In most cases, the cheese cured at 50° F. had a higher value than that cured at 60° F. These statements hold good for the twenty weeks during which the cheeses were kept at the three different temperatures. If the cheese cured at 60° F. had been kept for a longer period, it would have shown serious decrease in value.

In the case of lot VI, the value was the same for all temperatures on December 15, when the cheese was about eight weeks old. And this lot was of so much better quality that it was assigned a value above the 13-cent basis, in proportion to its score above 95 points. Two months later, there was no difference at the temperature of 40° and 50° F., but the cheese kept at 60° had a lower value than the cheese kept at the lower temperatures. In April, when the cheese was about twenty-five weeks old, there was a little difference in favor of the lower temperatures.

(2) In comparing the cheese covered with paraffin (lot VI, Ap and Bp) with that left in natural condition (lot VI, An and Bn), there was no difference in their value during the first seventeen weeks at the temperatures 40° and 50° F. At 60° F., at the end of seventeen weeks, the cheese covered with paraffin was valued at a quarter of a cent a pound more than the unparaffined. When the cheese kept at 40° F. was twenty-five and thirty-two weeks old, there was no difference in value between the paraffined cheese and that not paraffined; but in the cheese kept at 50° F. there was, at the end of twenty-five weeks, an increased value of a quarter of a cent a pound in favor of the paraffined cheese. It thus appears that the results are more marked at higher temperatures than at lower temperatures in favor of the paraffined cheese, but even then only after the first few months of ripening. The chief value of paraffining cheese appears to be in preventing loss of moisture and in keeping the surface of the cheese free from molds.

(3) If we average the results obtained with the different lots of cheese, we have the following figures:

Value per pound of cheese cured at different temperatures.

Date of examination.	At 40° F.	At 50° F.	At 60° F.
	Cents.	*Cents.*	*Cents.*
Dec. 15, 1902	13.300	13.175	12.950
Feb. 13, 1903	13.275	13.050	12.675
Apr. 9, 1903	13.525	13.325	.....

At the end of ten weeks the cheese cured at 40° F. was worth 12½ cents more per 100 pounds than the cheese cured at 50° F. and 35 cents more than that cured at 60° F. The cheese cured at 50° F. was worth 22½ cents per 100 pounds more than that cured at 60° F.

At the end of twenty weeks the cheese cured at 40° F. was worth 22½ cents more per 100 pounds than the cheese cured at 50° F. and 60 cents more than that cured at 60° F., while that cured at 50° F. was worth 37½ cents per 100 pounds more than that cured at 60° F.

At the end of twenty-eight weeks the cheese cured at 40° F. was worth 20 cents more per 100 pounds than that cured at 50° F.

Increased receipts from cheese cured at low temperatures and covered with paraffin.—We have seen that the curing of cheese at low temper-

atures has the effect of (1) preventing loss of moisture and (2) increasing the value of the cheese. Therefore, we not only have more cheese to sell but can sell it at a higher price. Taking cheese twenty weeks old as a basis for comparison, we know how much weight is lost at different temperatures and also the difference in price. From these figures the following tabulated statement is given:

Money returns at several temperatures.

Temperature of curing.	Cured cheese equivalent to 100 pounds of green cheese.	Market price of 1 pound of cheese.	Receipts from cheese.
° *F.*	*Pounds.*	*Cents.*	*Dollars.*
40	96.2	13.275	12.77
50	95.2	13.050	12.42
60	92.2	12.675	11.69

These figures indicate that from 100 pounds of green cheese put into the curing room we were able to realize from that cured at 40° F. 35 cents more than from cheese cured at 50° F., and $1.08 more than from that cured at 60° F. From the cheese cured at 50° F. we received 73 cents more a hundred pounds than from that cured at 60° F.

If we compare our results obtained with cheese covered with paraffin with those given by cheese not so covered, we have the following tabulated statement:

Cured cheese equivalent to 100 pounds of green cheese and comparative value of that paraffined and unparaffined.

Temperature of curing room.	Cured cheese equivalent to 100 pounds of green cheese.		Value of 1 pound of cheese.		Receipts from cheese.	
	Paraffined.	Not paraffined.	Paraffined.	Not paraffined.	Paraffined.	Not paraffined.
° *F.*	*Pounds.*	*Pounds.*	*Cents.*	*Cents.*	*Dollars.*	*Dollars.*
40	99.7	96.2	14.25	14.25	14.21	13.70
50	99.5	95.2	14.25	14.25	14.19	13.56
60	98.6	92.2	13.75	13.50	13.56	12.45

At 40° F. the difference in favor of the paraffined cheese is 51 cents for 100 pounds of cheese originally placed in the curing room; at 50° F. the difference is 63 cents, and at 60° F., $1.11. Covering cheese with paraffin results in greater saving at higher temperatures than at lower temperatures.

Comparing paraffined cheese cured at 40° F. with unparaffined cheese cured at 60° F., we find a difference of $1.76 for 100 pounds of cheese in favor of the paraffined cheese and the lower temperature.

[Continued from 2d page of cover.]

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